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February 2013

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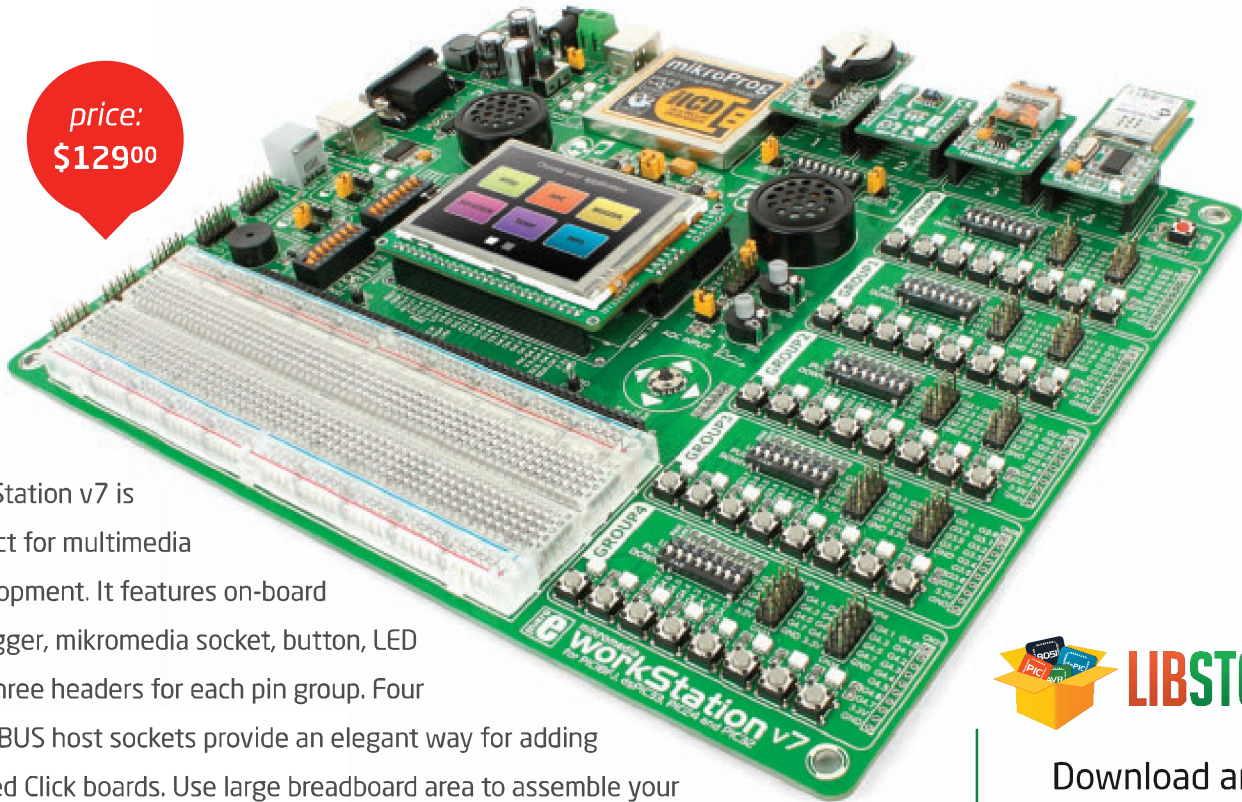
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Part No. NNDK-PK70EXNTP-KIT: \$399.00



# mikromedia workStation<sup>v7</sup>

for PIC18FJ<sup>®</sup>, dsPIC33<sup>®</sup>, PIC24<sup>®</sup>, and PIC32<sup>®</sup>

price:  
\$129<sup>00</sup>



workStation v7 is perfect for multimedia development. It features on-board debugger, mikromedia socket, button, LED and three headers for each pin group. Four mikroBUS host sockets provide an elegant way for adding desired Click boards. Use large breadboard area to assemble your custom electronics. This miracle board is fantastic for education as well. We made sure to provide a rich set of libraries and examples for our mikroC, mikroBasic and mikroPascal compilers which facilitate development.



Download and install **FREE Board Support Package** libraries from the Libstock website.  
[www.libstock.com](http://www.libstock.com)



## PIC18FJ, dsPIC33, PIC24 or PIC32?

workStation v7 supports all mikromedia boards with Microchip<sup>®</sup> microcontrollers. Easily switch to the one you need.

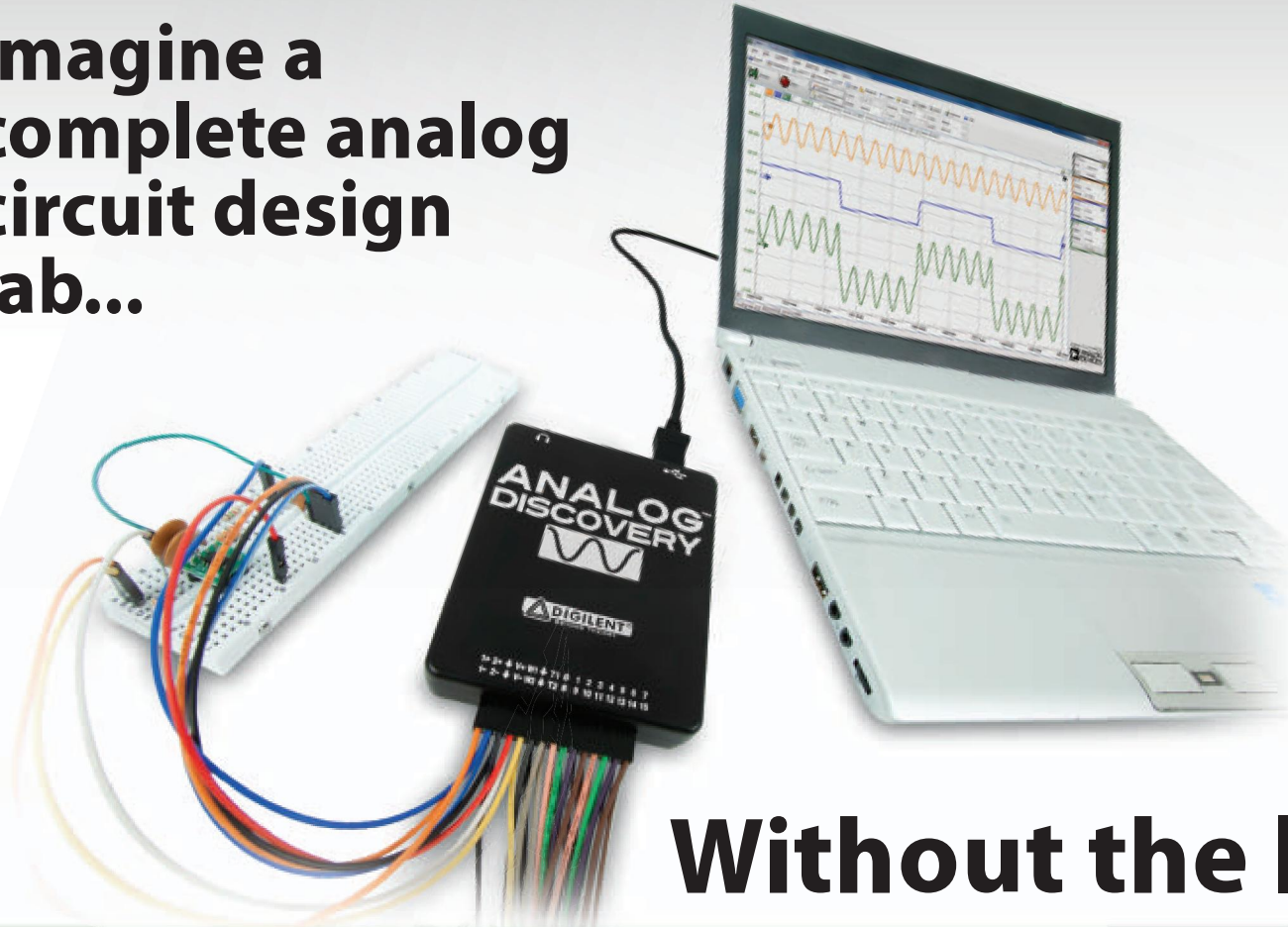
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Main picture includes: mikromedia workStation v7, mikromedia for PIC32, WiFi PLUS click, THERMO click, RTC2 click and SHT11 click.  
mikromedia and click boards are sold separately!



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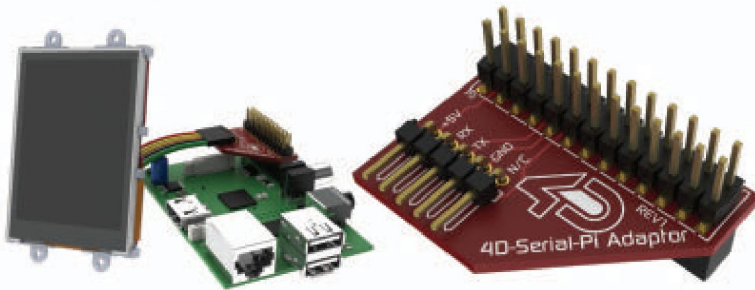
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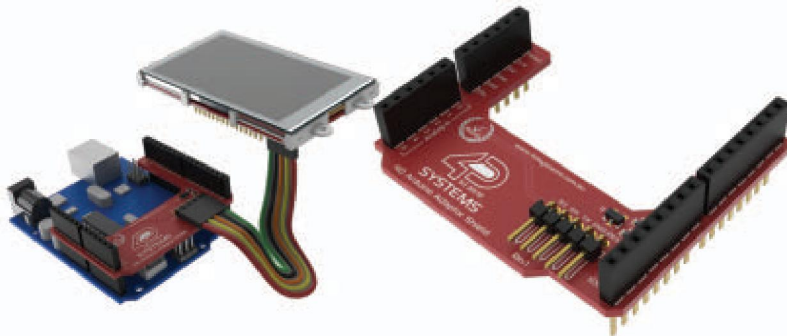
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■ By Thomas Henry

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■ By Sam Gailbreath and Rick Peterson

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■ By Bryan Bergeron

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## Kits for Electronics Enthusiasts

### Learn all about Arduino

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs (includes Jaycar stepper motors). Arduino projects can be stand-alone, or they can be communicated with software running on your computer. These Arduino development kits are 100% Arduino compatible. Designed in Australia and supported with tutorials, guides, a forum and more at [www.freetronics.com](http://www.freetronics.com). A very active worldwide community and resources are available with many projects, ideas and programs available to freely use.

#### Arduino Experimenters Kit

**Cat. XC-4262**

Everything you need to get started for a fun range of electronics and Arduino related projects. Servo motor, lights, buttons, switches, sound, sensors, breadboard, wires and more are included with a Freetronics Eleven Arduino compatible board in this extensive hobby experimenter kit.

- Comprehensive instructions included
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**\$65.00\***



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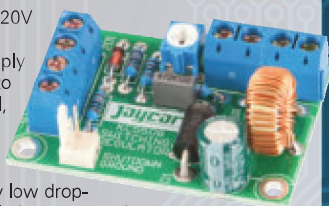
#### Switching Regulator Kit

**Cat. KC-5508**

Outputs 1.2 to 20V from a higher voltage DC supply at currents up to 1.5A. It is small, efficient and with many features including a very low drop-out voltage, little heat generation, electronic shutdown, soft start, thermal, overload and short circuit protection. Kit supplied with PCB, pre-soldered surface mounted components.

- PCB: 49.5 x 34mm

**\$29.00\***



#### Garbage and Recycling Reminder Kit

**Cat. KC-5518**

Easy to build kit that reminds you when to put which bin out by flashing the corresponding brightly colored LED. Up to four bins can be individually set to weekly, fortnightly or alternate week or fortnight cycle. Kit supplied with silk-screened PCB, black enclosure (83 x 54 x 31mm), pre-programmed PIC, battery and PCB mount components.

- PCB: 75 x 47mm

Note: Product will vary from photo shown

**\$21.75\***



#### 20A 12/24VDC Motor Speed Controller Kit

**Cat. KC-5502**

Control the speed of 12 or 24VDC motors from zero to full power, up to 20A. Features optional soft start, adjustable pulse frequency to reduce motor noise, and low battery protection. The speed is set using the onboard trimpot, or by using an external potentiometer (available separately, use RP-3510 \$1.50).

- Kit supplied with PCB and all onboard electronic components
- Suitable enclosure UB3 case, HB-6013 \$2.50 sold separately

**\$29.00\***



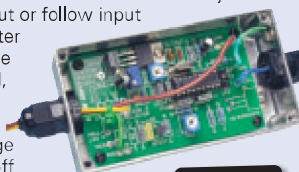
#### High-Energy Electric Ignition Kit for Cars

**Cat. KC-5513**

Use this kit to replace a failed ignition module or to upgrade a mechanical ignition system when restoring a vehicle. Use with virtually any ignition system that uses a single coil with points, hall effect/lumenition, retractor or optical sensors (Crane and Piranha) and ECU. Features include adjustable dwell time, output or follow input option, tachometer output, adjustable debounce period, dwell compensation for battery voltage and coil switch-off with no trigger signal.

- Kit supplied with silk-screened PCB, diecast enclosure (111 x 60 x 30mm), pre-programmed PIC and PCB mount components for four trigger/pickup options

**\$36.00\***



#### 'The Champion' Audio Amplifier Kit with Pre-Amplifier

**Cat. KC-5519**

Suitable for general-purpose audio projects and supports microphone and electric guitar input. It uses the AN7511 audio IC to deliver 2W music power into 8 ohms from a 9 to 12V supply. Features low distortion, two inputs (mixed 1:1), mute and standby control. Power from 4 - 13.5VDC. See website for specifications.

Kit supplied with silk-screened PCB, heatsink and PCB mount components.

- PCB: 101 x 41mm

**\$14.50\***



#### 10A 12VDC Motor Speed Controller Kit

**Cat. KC-5225**

Ideal for controlling 12V DC motors in cars such as fuel injection pumps, water/air intercoolers and water injection systems. You can also use it for headlight dimming and for running 12V DC motors in 24V vehicles. The circuit incorporates a soft start feature to reduce inrush currents, especially on 12V incandescent lamps. Includes PCB and all electronic components.

- Kit includes PCB plus all electronic components to build the 10A version.
- PCB: 69 x 51mm

**\$18.00\***



#### Speedo Corrector MkII Kit

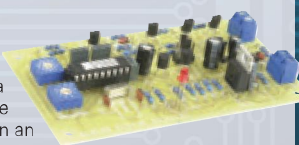
**Cat. KC-5435**

When you modify your gearbox, diff ratio or change to a large circumference tyre, it may result in an inaccurate speedometer. This kit alters the speedometer signal up or down from 0% to 99% of the original signal. The input setup selection can be automatically selected and features an LED indicator to show when the input signal is being received. Kit supplied with PCB with overlay and all electronic components.

- PCB: 105 x 61mm
- Recommended box: UB3 (use HB-6013 \$2.50)

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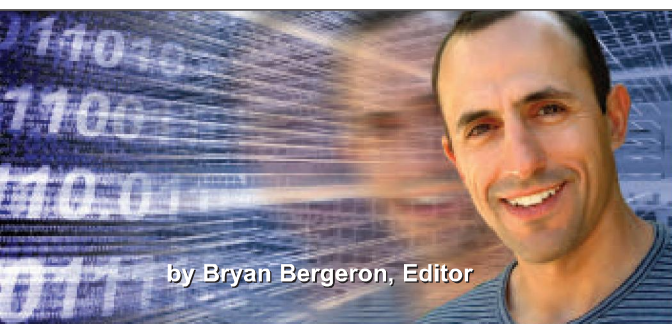
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by Bryan Bergeron, Editor

# DEVELOPING PERSPECTIVES

## The Stuff Dreams Are Made Of

It seems like déjà vu all over again. I endured a noisy, 15 cps dot-matrix printer for years until I could afford a quality laser printer at home. Although Apple sold me a LaserWriter at a discount, I paid well over \$1,000 for the new device. No more walking to the corner printer with my disc for sharp printouts. Personal publishing reached the tipping point, and, well, the rest is history.

Recently, I made the same sort of move, for the same relative investment in 3D printing. I was tired of paying the setup fees and waiting days for the commercial printing services. Besides, affordable 3D printers have been around for well over a decade. More importantly, the software tools for creating 3D objects have matured, in part because of competition in the software game design market. Besides, high-res 3D scanners are almost affordable.

So, why now? Why not wait for the next model in six months? Well, part of the motivation to move on the technology was a chance meeting with Ken Gracey, President of Parallax. He's using a home 3D printer to prototype next-generation quadcopters and other drones. Turns out that having immediate

feedback on the merits of a design do wonders for turnaround time. It's like walking to the corner store to use a laser printer versus having one on your desk. You can try four or five iterations of a design where you may have had time for only one before.

Making the jump to 3D printing is relatively painless, checkbook permitting. One of the key decisions you'll need to make up front is the working material or filament. The two main types of filament are ABS plastic — used in just about everything — and the theoretically more eco friendly PLA.

One of the many advantages of ABS plastic is that the colors are gorgeous and it's easy to work with the printed objects. PLA, in contrast, has a milky translucent appearance when printed and is more brittle, so therefore can be more difficult to work with.

Both plastics should be handled in a well-ventilated shop, but PLA appears to have fewer toxic fumes. On a positive note, if you're used to

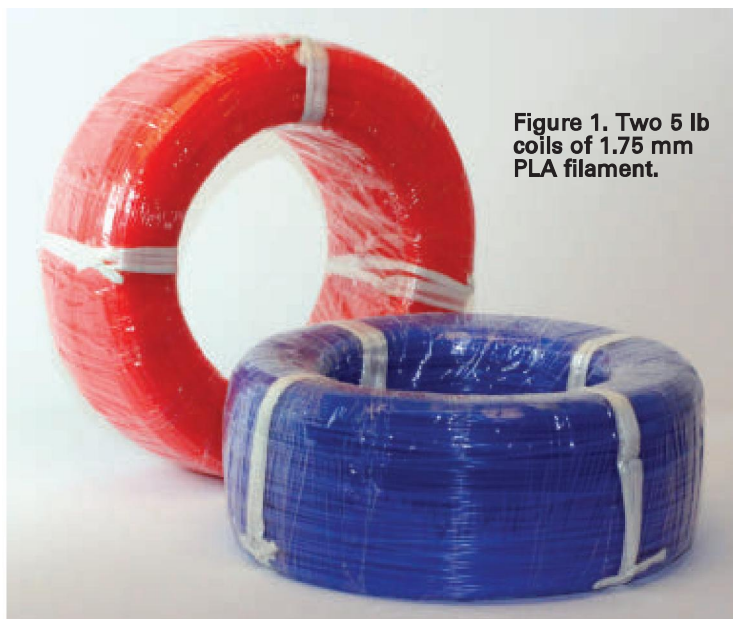
working with a computer numerical controlled (CNC) or manual milling machine, you'll appreciate the quiet, dust-free 3D printing process.

From a cost perspective, don't get the idea that you're going to start printing toys and selling them on eBay. At-home machines are great for rapid prototyping, but compared with what's available from the commercial printing houses, you'll produce the equivalent of dot matrix output compared with their laser printer output. Moreover, just as the old dot matrix machines had a super-slow letter-quality mode, you can do the same with at-home 3D printers. Just don't expect to see any output for a while.

The greatest economic challenge at the moment is the cost of source material. I've found both PLA and ABS on eBay for about \$20/lb plus shipping, when purchased in 5 lb rolls (such as the two rolls of PLA in **Figure 1**). It pays to shop around for materials, as I've seen adds on 3D printer sites asking for \$35 or more for 1 Kg spools. I

suspect that somewhere in China, someone is planning a \$300 3D printer and \$10/lb plastic filament for the US market.

So, why not wait for the inevitable announcement of a price drop? Why not let the 50-60 3D printer suppliers duke it out until the Apple and Microsoft equivalents appear? For one, you'll miss out on all the fun. If you lived through the days of the Commodore-64, TRS-80, Commodore Amiga, and NEXT, you know what



**Figure 1. Two 5 lb coils of 1.75 mm PLA filament.**



# NUTS AND VOLTS

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I'm talking about.

Second — and most importantly — it takes time to wrap your head around 3D printing. Think back to all of the worthless flyers and incomprehensible manuscripts that were generated with the help of the first home laser printers. Simply because you own a printer doesn't mean you can write or format a document correctly.

The same holds true for 3D printing. You don't just 'print' a quadcopter. You need to know, for example, about methods of cutting weight with minimal loss in strength, and how to arrange your objects in 3D space so that printing is quick and waste is minimal. Then, there's finishing the printed object to remove support splines or ripples from the low-resolution printing. It's art and science.

Even if you don't buy into the world of 3D printing today, at least check the status of the industry and then recheck it in six months. Pay attention to the hardware printer proper, but also the software tools and the all-important peripherals, including 3D scanners and associated software.

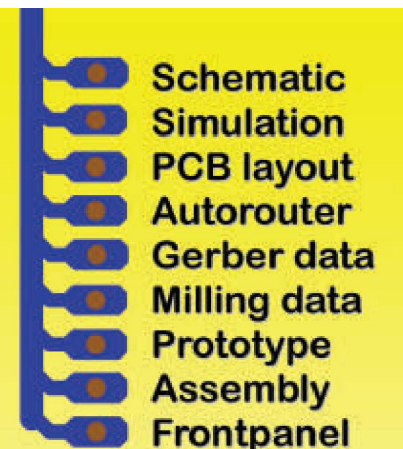
What's the old saying about the future and plastics? Clearly, it's what dreams are made of. **NV**

## READER FEEDBACK

### GETTING THE RIGHT TONE

In your Developing Perspectives column on the Lost World of Tubes in the December 2012 issue, you mentioned that at low volume settings tube amps make annoying hisses and pops. While vacuum tubes are more prone to hum, hiss, and microphonics than good solid-

*Continued on page 76*

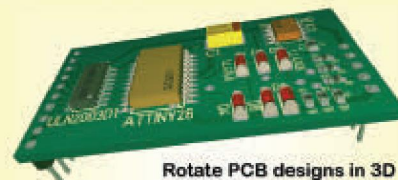


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## ADVANCED TECHNOLOGY



■ Ames Lab researcher Min Cai readies a metal-oxide OLED inside a laboratory "glove box."

### BETTER DISPLAYS, NO MORE INDIUM

All of today's flat screen displays used in computers, TV sets, and cell phones rely on indium tin oxide (ITO) to form transparent anodes used in the devices. Unfortunately, ITO has a few drawbacks including its breakability, limited supply, and rising cost. As of this writing, a half pound ingot of pure indium will set you back \$179 which doesn't put it in the same range as gold, but it's getting up there with silver. Finding

a substitute is a bit problematic, as very few conductors are also transparent.

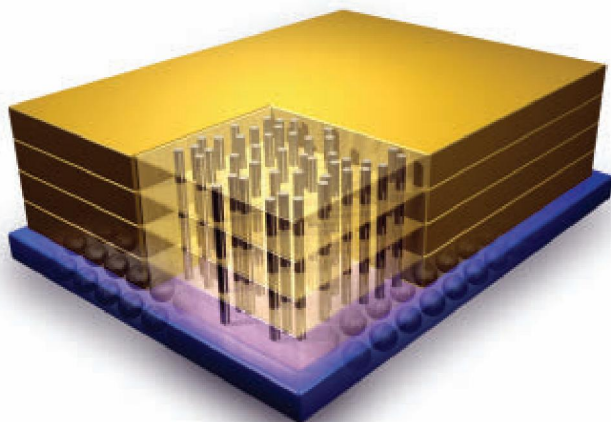
A fair amount of research has been undertaken with the aim of replacing it with a much cheaper metal oxide (zinc oxide). At present, you can buy a pound of zinc for less than \$1. However, some scientists at the Department of Energy's Ames Laboratory ([www.ameslab.gov](http://www.ameslab.gov)) have taken a different track and figured out how to replace it with a polymer that's commonly used in organic light-emitting diodes (OLEDs). Known as PEDOT:PSS [short for poly (3,4-ethylene dioxythiophene):poly(styrene sulfonate), if you must know], the material has been around for years but was never considered conductive or transparent enough to replace ITO.

Ames researcher Min Cai and his colleagues have now figured out a way to improve those characteristics through multi-layering and other techniques. The result is an anode that is at least 44 percent more efficient than ITO is. In addition, it is not brittle so it can be used on flexible substrates. The main obstacle appears to be the cost of manufacturing PEDOT:PSS which generally involves an expensive thermal evaporation deposition process. However, the use of a new solution processing technique for small-molecule OLEDs has been demonstrated and documented in the journal *Advanced Materials* (accessible at [onlinelibrary.wiley.com](http://onlinelibrary.wiley.com)), so an economical path to ITO-free displays may be in the offing. In the meantime, you might want to reconsider any investments you have in zinc mining operations, as indium is a lucrative by-product of zinc production. ▲

### MEMORY CUBES POISED FOR PRODUCTION

A less speculative breakthrough has been announced by IBM ([www.ibm.com](http://www.ibm.com)) and partner Micron Technology ([www.micron.com](http://www.micron.com)) which very soon will be manufacturing Micron's Hybrid Memory Cube (HMC). This represents the first commercial CMOS application of through-silicon vias (TSVs). Each memory cube consists of a stack of individual chips that are connected by vertical vias as shown in the artist's rendering. The devices will be built using IBM's 3D manufacturing technology at the company's semiconductor fab installation in East Fishkill, NY, employing the 32 nm, high-K metal gate process. The result is a DRAM that delivers a new level of bandwidth and power efficiencies. The HMC prototypes clock in at 128 GB/s, compared to today's state-of-the-art devices that offer only 12.8 GB/s. It also uses 70 percent less energy to transfer data, and eats up 90 percent less board space than a conventional chip.

According to IBM Fellow Subu Iyer, "The manufacturing process we are rolling out will have applications beyond memory, enabling other industry segments as well. In the next few years, 3D chip technology will make its way into consumer products, and we can expect to see drastic improvements in battery life and functionality of devices." ▲



■ A new memory design from IBM and Micron offers a leap in memory speed and a 90 percent smaller footprint.



Discuss this article in the Nuts & Volts forums at <http://forum.nutsvolts.com>.

## COMPUTERS AND NETWORKING

### WORLD'S THINNEST UHD MONITOR

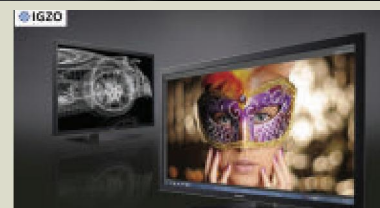
If you work in a profession where monitor resolution is critical (e.g., design, video, or a medical field), or even if you just can't be satisfied with run-of-the-mill HD TV, Sharp has a treat for you. Slated for release in Japan this month (and presumably in the US soon after) is the PN-K321 — a 32 inch 4K IGZO LCD display. In case you haven't been following such things, the "4K" designation on a monitor means that you get approximately 4,000 pixels in the horizontal plane; in this case, 3840 x 2160 — four times what you are probably viewing in your living room. This qualifies it under the definition of "ultra high definition."

A slew of companies offer 4K units, but most will cost you at least as much as a new car, such as ViewSonic's prototype VP3280-LED which offers the same resolution, a slightly smaller screen, and is slated to cost in the neighborhood of \$30,000-40,000 when it hits the market. The IGZO part stands for "indium gallium zinc oxide" which replaces amorphous silicon for the active layer of the screen, providing 40 times the electron mobility and enabling much

■ Sharp's PN-K321 offers 8.3 megapixels in a 32 inch UHD display.

smaller pixels. The PN-K321 is also presented as the industry's thinnest 4K monitor at only 3.5 mm. It includes two HDMI connectors and a pair of built-in speakers in a package that weighs 7.5 kg (16.5 lb). The unit is, relatively speaking, reasonably priced at \$5,500.

Reportedly, Sharp also intends to roll out an 80 inch version for \$12,000, so you might want to wait for that one. If resolution is really that important to you, however, it might be worth holding out until the 8K units (7680 x 4320 pixels) arrive. ▲



### PUT A BEAST IN YOUR BOX

Most of us bottom feeders use the same method for memory upgrades: Log onto eBay, buy the cheapest bag of chips that will function in our machines, and pop them in. For hard-core gamers, big-time graphics and video users, and overclock geeks, however, that just isn't good enough. Aimed at those folks is Kingston's HyperX Beast — a line of high performance, high capacity memories recently added to the Predator family. The devices are available in kits with frequencies between 1,600 and 2,400 MHz; as two, four, and eight DIMMs; and in capacities from 8 to 64 GB.

The Beasts are designed to work with third-gen Intel Core i5 and i7 processors plus the latest AMD A-Series chips. They are "XMP ready," meaning that they can employ the Intel® Extreme Memory Profile feature that allows you to overclock compatible DDR3 memory to exceed standard

■ Kingston's HyperX Beast memory chips for hard-core users.



performance specifications using enhanced frequencies, timings, and voltage (1.5V to 1.65V). They're even meaner looking with their "eye-catching aggressive heat spreader design," although it's not clear how much of the design is functional and how much exists for aesthetics. As you might expect, the list prices are a bit daunting, but as of this writing, a 2 x 8 GB kit listing for \$240 can be had online for just under \$130. ▲

### AND MAYBE ONE IN YOUR CAR

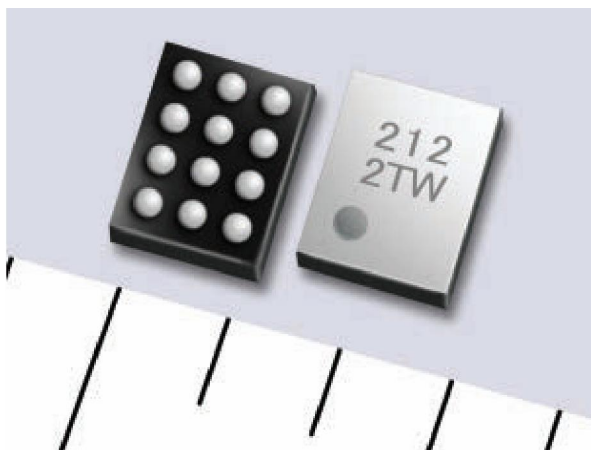
Let's say you're driving down the interstate, press your foot on the gas, and suddenly hear a female voice whining at you about the dangers of sudden acceleration. Or, you hit the brake pedal and the voice yowls "hard braking!" Or, you take some other disapproved action and meet with such responses as "Vehicle wandering!" "Bad lane change!" or "No talking or texting!" Sure, the annoying voice could be coming from your wife or mother-in-law, but soon it could also be emanating from your smartphone, thanks to an app called "Mobile Life Guard."

According to Prof. Ram Dantu (the app's developer), "After you put the phone on your armrest and turn it on, it

will sense the way you drive — the way you change lanes, the way you brake, tailgating — all aspects of your driving." In response, it will provide a continuous narrative of your navigational shortcomings.

Fortunately, there is no indication that it will also advise you to change the radio to a station that plays Michael Bolton or stop looking at female joggers. This cyber-nagger was developed with a \$50,000 grant from the US government's National Science Foundation, but users nevertheless will be required to pay a one-time or annual subscription fee. No information was provided about where to sign up, but if you stop and ask for directions, you could find out.. ▲

# CIRCUITS AND DEVICES



■ The LC898212XA-MH autofocus controller IC offers faster action, lower power consumption, and a space-saving design.

## IMPROVED AUTOFOCUS CONTROLLER

Most cell phone cameras rely on an autofocus mechanism that uses a tiny motor to position the lens. As one might expect, complaints related to this function tend to be related to the machinery's slow operation and high power consumption. Now, both factors are addressed by a new chip from ON Semiconductor ([www.onsemi.com](http://www.onsemi.com)), designed specifically for smartphones.

According to the company, the LC898212XA-MH control IC "is highly integrated, programmable, and provides fast, accurate auto focus convergence while consuming less power and generating less noise interference than competing solutions." The chip features digital logic with a closed-loop control system and a function for a positioning sensor. The control circuit filter coefficients are adjustable via an I<sup>2</sup>C interface, so it can be programmed to achieve the optimal convergence time for a variety of actuators.

An integrated ADC (analog-to-digital converter) provides 10-bit precision for improved focus control. No information was provided about which makes and models of smartphones will be sporting the new controller, but the company does have a division devoted to Sanyo products. ▲



■ These sexy mannequins are looking back at you.

## EYEESEE YOU SEE ME

The next time you find yourself stopping to stare at a scantily dressed mannequin in a department store, consider that she just might be looking back at you and even recording and analyzing your behavior. As recently reported by Bloomberg ([www.bloomberg.com](http://www.bloomberg.com)), the Italian mannequin maker Almax SpA ([www.almax-italy.com](http://www.almax-italy.com)) is now selling a version of its polystyrene fashion dummies that has been fitted with the same basic technology used to identify criminals in airports.

Inside the EyeSee mannequin's head is a camera that sends images to facial-recognition software just like police use. In addition, it also logs the age, gender, and race of gawkers, plus the number of people who have stopped to look and how long they stayed. In theory, the data is used only for marketing purposes. For example, one store introduced a new line of children's clothing after discovering that most of its afternoon traffic consisted of youngsters. Another added Chinese-speaking staff

after discovering that a third of its visitors after 4:00 P.M. were Asian.

There are already signs that "mission creep" is likely to set in, with some retailers wanting to keep track of big spenders so they can offer them discounts and rewards. And, there's no reason why the system couldn't detect those fancy Italian shoes you're wearing and respond by displaying information about a shoe sale on the 12th floor. Some have expressed concern that such "profiling" raises potential legal and ethical issues that have yet to be resolved.

At present, there are only "a few dozen" of the snoopy dolls installed in the US and Europe, but with the increasingly tough high-end retail market, customer data becomes more critical to the development of marketing strategies. On the positive side, the \$5,500 price tag may keep them from becoming a huge part of the mannequin population. ▲



# INDUSTRY AND THE PROFESSION

## RETIRED SUPERCOMPUTERS BACK ON THE JOB

Most retired large-scale computers end up on the scrap heap because the cost of maintaining them often exceeds the price of a new machine with equal crunching power. Plus, there's a fair amount of gold to be mined from them that hills. Recognizing that access to decommissioned supercomputers can be quite valuable to researchers and students, Los Alamos National Laboratory recently created the Parallel Reconfigurable Observational Environment (PRObE) center at its Los Alamos Research Park, about 35 miles outside of Santa Fe, NM. The center contains more than 1,000 computers and 2,000 cores from retired Los Alamos systems named Coyote and Cuda, and more will be added as unclassified systems hit retirement age.

According to Los Alamos, "The facility will be available to researchers from US universities, as well as to summer undergraduate students through the Los Alamos Institutes. No other facility exists in the world for students and researchers to work out the complexities in designing and testing concepts for supercomputers



■ Los Alamos Director Charlie McMillan talks with Andree Jacobson of the New Mexico Consortium in the PRObE machine room.

at this large scale."

The center is funded by a \$10 million grant from the National Science Foundation and is operated by the New Mexico Consortium and collaborators at LANL, Carnegie Mellon University, and the University of Utah.

To find out if there's a slot for you at the center, visit [www.la-rp.org](http://www.la-rp.org) and fill in the form, or call Kevin Holsapple at (505) 661-4806. **NV**

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## HERDING DATA OVER BRIDGES

**Small autonomous networks are wonderful things. Data flies about from node to node. Relays, LEDs, and switches submit to the modulated RF energy. Things are good. Well, things are good until you want to intrude on the data exchanges and harvest the bits and bytes for human consumption. Small self-contained networks are like cattle. You can fence them in and they get along just fine. When you need access to them, you open the gate and enter their domain. Our silicon cattle normally stroll around in the Industrial, Scientific, and Medical (ISM) grass and feed on the 802.15.4 protocol. To keep tabs on the data within the herd, we as humans must have similar beasts that can speak to the silicon cattle and to us. That interpreter is known as a bridge. Once we "cross the bridge" with our data, we can distribute it using a gateway.**

**T**his month's discussion will center on moving data back and forth between a small embedded network and the Internet. It sounds like a daunting task. I'll show you how to make it look easy.

### CROSSING THE FIRST BRIDGE

The radios in our small network can pass data between each other till the cows come home. What good is that data if we can't access and use it? Odds are the radios are controlled by something. That something is usually some type of microcontroller. The microcontroller is the first bridge that the data flying within our tiny network crosses.

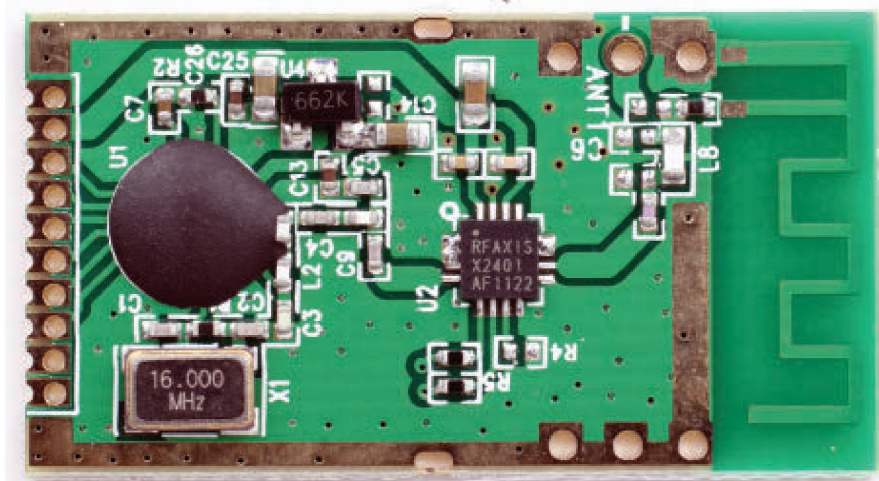
For example, the radio you see in **Photo 1** is a Lemos LMX-ISM-242-LR. The LMX-ISM-242-LR is a high power version of the LMX-ISM-242-SR we

discussed in last month's Design Cycle. The LMX-ISM-242-LR contacts other LMX-ISM-242-LRs and LMX-ISM-242-SRs in the network using GFSK-modulated packets.

The modulated data packets originated at the microcontroller level and were passed to the radio over its SPI bridge. Received packets take the opposite route over the bridge and move from the radio's demodulator through the SPI portal and into the microcontroller's volatile memory area. Once the data is placed in the microcontroller's SRAM, we can use the microcontroller's instruction set to either move a modified data packet over the SPI bridge back to the radio, or send the data along its way over another path.

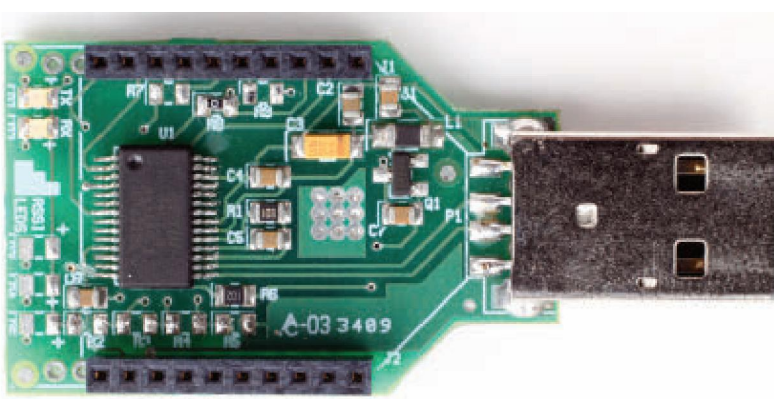
### A DROP-IN GATEWAY

PANs (Personal Area Networks)

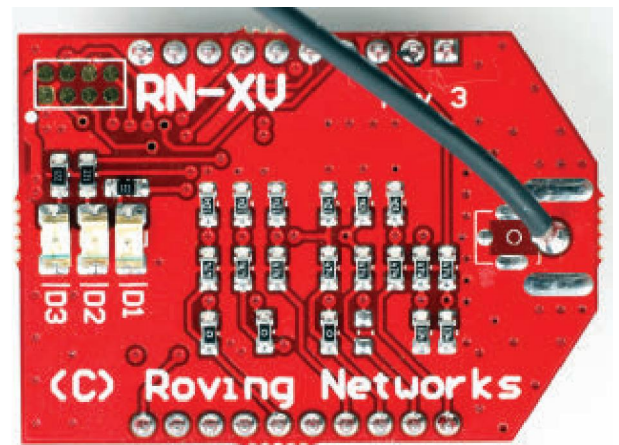


■ **PHOTO 1.** The LMX-ISM-242-LR's maximum power output is 100 mW. We can put this radio to work using the same driver package that we constructed for the LMX-SR.





■ **PHOTO 3.** This carrier was originally designed for an 802.15.4 radio. The carrier supplies power and includes an FTDI USB-to-UART bridge IC.



■ **PHOTO 2.** The Microchip RN-XV is an 802.11 b/g Wi-Fi device that is designed to replace 802.15.4 radios. The RN-XV operates at 3.3 VDC and is able to connect directly to a PIC UART.

are not designed to carry data over great distances. So, we must ferry the PAN packets between the PAN-based microcontrollers and devices that have immediate access to a WAN (Wide Area Network) or the Internet.

There are many ways we can move data about with a microcontroller. Most advanced microcontrollers contain one or more UART, SPI, and I<sup>2</sup>C engines. I<sup>2</sup>C — which is short for Inter IC — is primarily used to logically interconnect integrated circuits. The LMX-ISM-242-LR (LMX-LR for short) can move data over the Ether at 1 Mbps. High speed serial data transfer is just a walk in the park for an SPI portal. A typical UART application will normally use data rates that are far below 1 Mbps.

PAN devices are engineered to move small amounts of data in bursts. Thus, UARTS with baud rates as low as 2400 bps can be utilized successfully in PAN environments. The LMX-LR transports data in a packet that can contain anywhere from one to 32 bytes. Even if a packet is transmitted every second, we can use a microcontroller's UART to easily move 32 bytes from Point A to Point B with a baud rate of 9600 bps.

If the device we're moving data to and from also contains a UART,

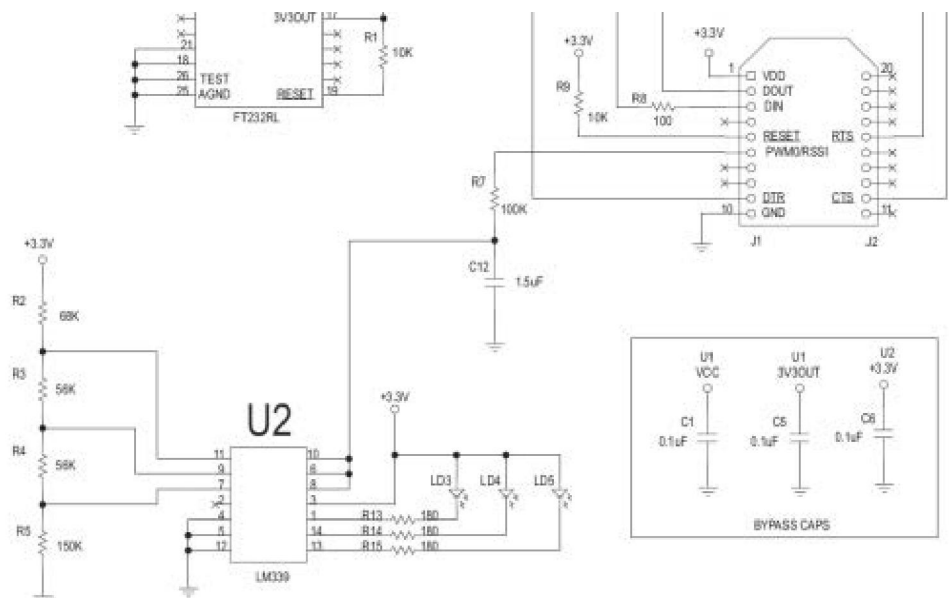
and the device and microcontroller operate at the same voltage level, the microcontroller and external device can communicate serially without the need for any additional interface hardware. UART intercommunication firmware is easily written. The ideal situation would utilize the relatively simple UART communication process to gain automatic access to a WAN, LAN, or the Internet.

The ideal solution is exposed in **Photo 2**. The Microchip RN-XV is a Wi-Fi drop-in replacement for similar 802.15.4 radios. Utilizing a UART interface and operating at 3.3 VDC, the RN-XV connects directly to a PIC's UART.

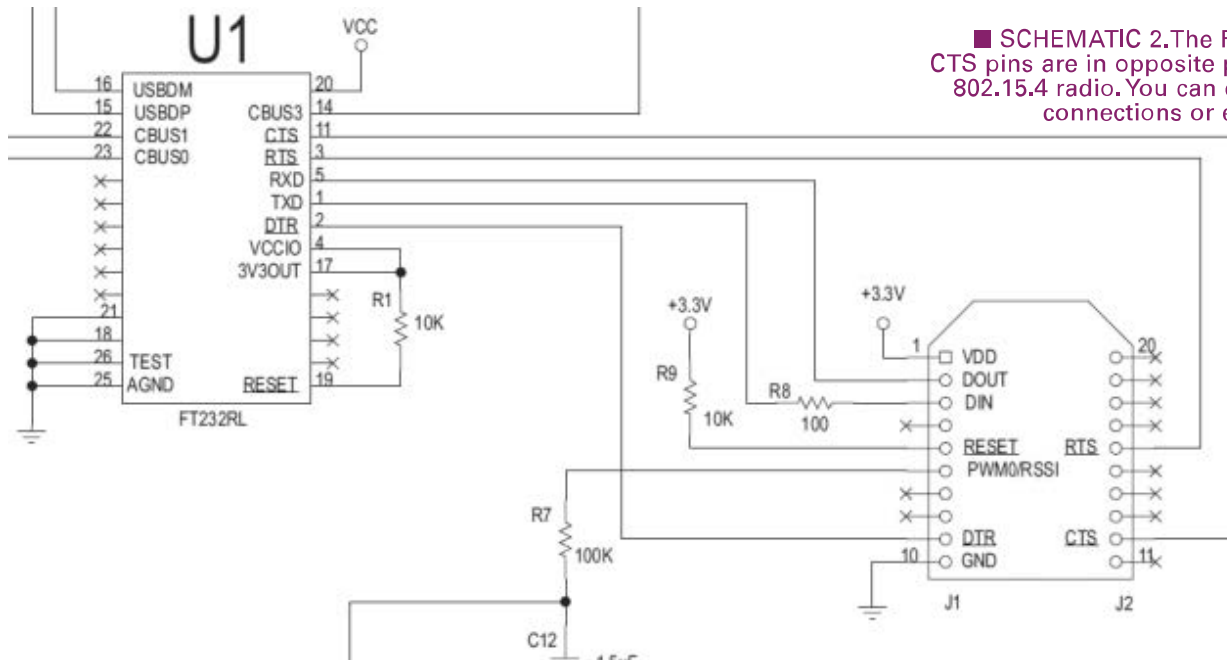
Only four physical connections are needed to convert RS-232

protocol to wireless Ethernet. The RN-XV comes loaded with a TCP/IP stack, and includes integral I/O pins and analog-to-digital converter (ADC) inputs. Built-in networking applications include HTTP and Telnet. The RN-XV can also act as an FTP, DNS, and DHCP client. UDP and TCP protocols are supported.

RN-XV setup is simple and can be done with a direct serial connection or remotely via Telnet. Initial configuration can also be performed by forcing the RN-XV into ad hoc mode. I chose to set up my RN-XV with a modified 802.15.4 radio carrier. The RN-XV and 802.15.4 radio are pin compatible as far as the power, ground, transmit,



■ **SCHEMATIC 1.** This is a partial schematic of the 802.15.4 radio carrier. To isolate the LM339 and the RSSI LEDs, remove R7. This will free the RN-XV GPIO5 pin for your use.



■ SCHEMATIC 2. The RN-XV RTS and CTS pins are in opposite positions of the 802.15.4 radio. You can either swap the connections or eliminate them.

and receive pins are concerned. The modification involved disabling the original carrier's RSSI circuitry. My modified RN-XV carrier can be seen in **Photo 3**.

**Schematic 1** shows us that the 802.15.4 radio module's pin 6 is the radio's RSSI output pin. The RN-XV does not have an RSSI pin in this position. Instead, pin 6 of the RN-XV is GPIO5. Removing resistor R7 will free GPIO5 and isolate the original RSSI circuitry. The second part of the

modification involves the RTS and CTS pins.

**Schematic 2** reveals that the original 802.15.4 RTS signal is located on pin 16. The RN-XV datasheet states that CTS resides on pin 16. So, we can either physically swap the RTS and CTS connections or simply cut the traces. If you look closely at **Photo 3**, you will see that I eliminated the traces.

The 802.15.4 radio carrier is sold by New Micros. You can obtain a complete schematic of this radio carrier from the New Micros website. I performed the modifications to eliminate anything that could possibly cause chaos. Once I felt comfortable with the RN-XV's operational characteristics, I plugged it into a stock New Micros 802.15.4 radio carrier. Everything worked just fine. So, if you don't plan to use RTS/CTS flow control or

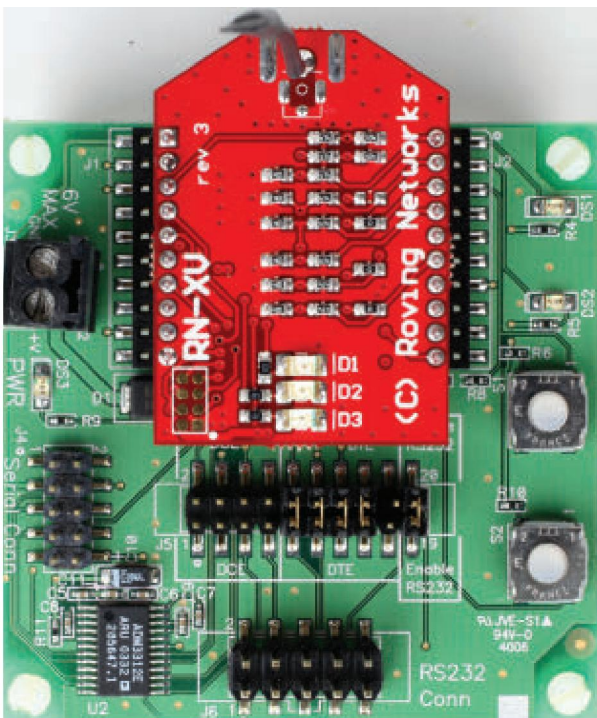
do anything with GPIO5, no modifications of the New Micros carrier are necessary.

## ROUTER SETUP

My Linksys router has dynamic DNS capability. When used in conjunction with a DynDNS account, I can (at any time) simply enter a preset host name to find my router and the RN-XV it supports via an Internet connection. Within my DynDNS account, I've set up a host name of *nutsvolts.dyndns-server.com*, which we will use to contact the RN-XV you see sitting in yet another 802.15.4 radio cradle in **Photo 4**.

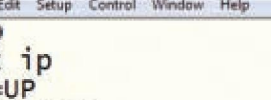
I re-enlisted this 802.15.4 radio carrier because it supplies the needed 3.3 volt power rail and provides easy access to the RN-XV's transmit and receive pins. The pushbuttons, LEDs, and RS-232 interface IC are still on the cradle because they aren't hindering the RN-XV's operation.

The DynDNS feature of the Linksys router allows us to associate the host name I created with the router. The next step involves creating and opening a port on the router. To keep things simple, we'll assign a port number of 8888 and link it to an IP address of 192.168.0.88. I activated port 8888



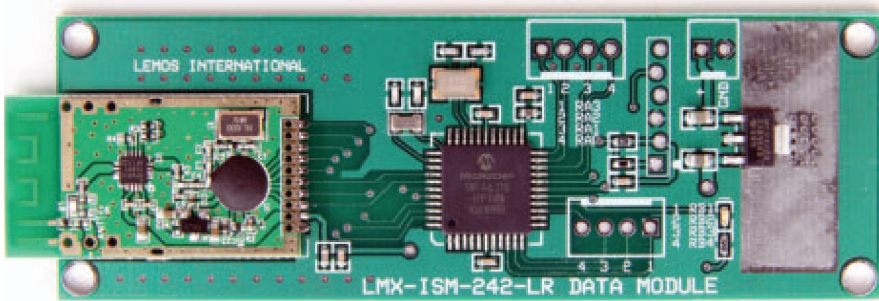
■ PHOTO 4. This is an old Rabbit 802.15.4 radio cradle. I verified that the voltage regulator was still working and plugged the RN-XV into the socket. No modifications were made to the cradle.





CMD  
get ip  
IF=UP  
DHCP=OFF  
IP=192.168.0.88:8888  
NM=255.255.255.0  
GW=192.168.0.1  
HOST=0.0.0.0:2000  
PROTO=UDP, TCP,  
MTU=1524  
FLAGS=0x7  
TCPMODE=0x4  
BACKUP=0.0.0.0  
<2.36>

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■ **PHOTO 5.** There is a ton of RF and compute horsepower in this shot. The 12 MIP PIC18F46J13 belongs to the nano-watt XLP family of low power microcontrollers. The 100 mW LMX-ISM-242-LR radio allows the sensor data processed by the PIC18F46J13 to be heard from afar.

```
HOST=0.0.0.0:2000
PROTO=UDP,TCP,
MTU=1524
FLAGS=0x7
TCPMODE=0x4
BACKUP=0.0.0.0
<2.36> save
Storing in config
<2.36>
```

That should be enough IP information to get us on the air. I issued a save command to make sure our work up to this point won't have to be repeated. The WLAN configuration commands are issued in the same way the IP commands were issued:

```
<2.36> set wlan ssid servo
AOK
<2.36> set wlan passphrase nuts
AOK
<2.36> get wlan
SSID=servo
Chan=11
ExtAnt=0
Join=1
Auth=WPA2
Mask=0x1fff
Rate=12, 24 Mb
Linkmon=0
Passphrase=nuts
TxPower=0
```

Most of the WLAN parameters are self-explanatory. The *Join* parameter tells the RN-XV to attempt to associate only with a router using servo as its

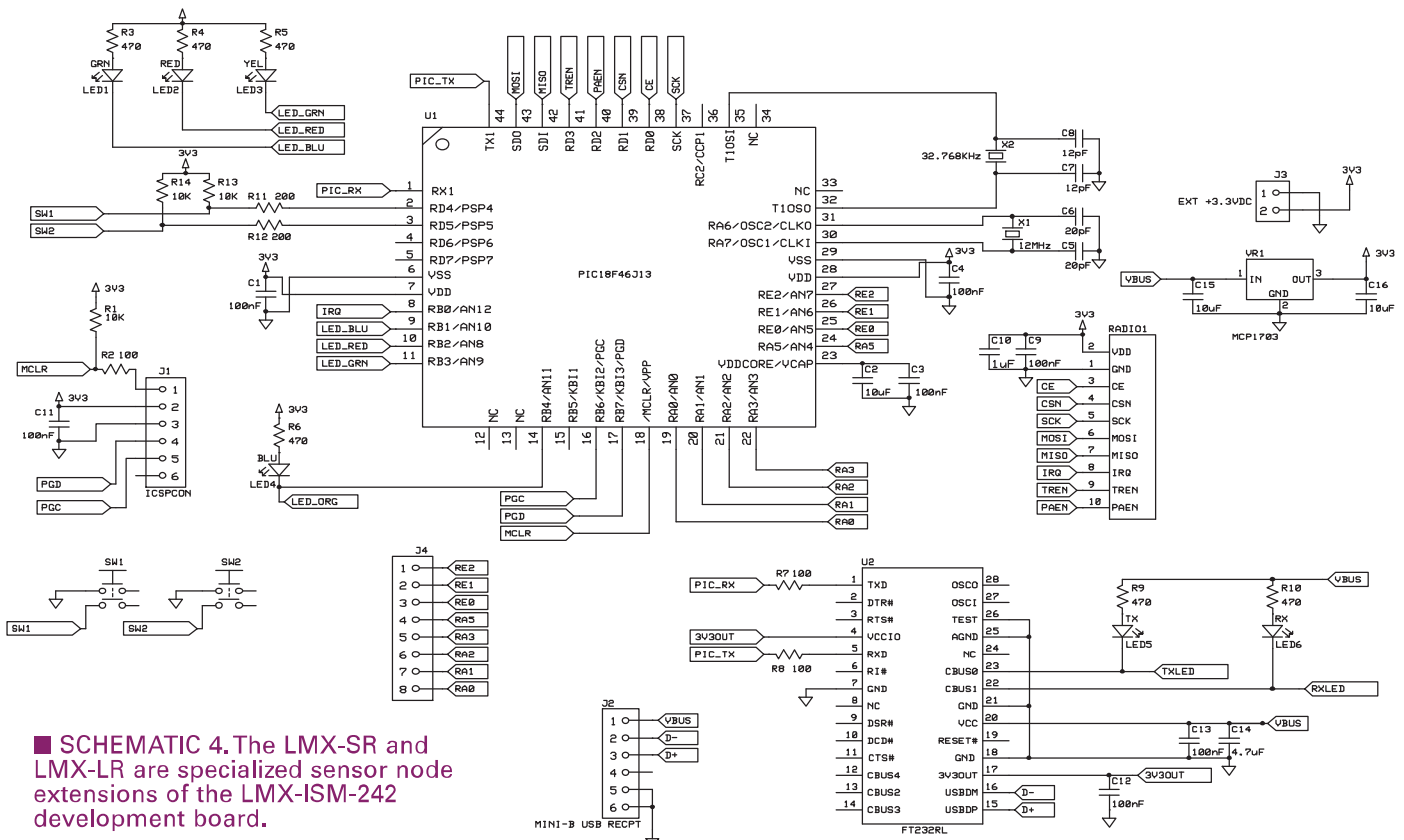
SSID. It's time to issue a *reboot* command and check our work:

```
reboot
*Reboot*WiFly Ver 2.36, 09-27-
2012 on RN-171
MAC Addr=00:06:66:80:3a:3c
Auto-Assoc servo chan=11
mode=WPA2 SCAN OK
Joining servo now..
*READY*
Associated!
Using Static IP
Listen on 8888
```

We're looking good. Let's test that DynDNS connection. The necessary connection details are outlined in **Screenshot 1**.

## CONTACT!!!

The response you see in **Screenshot 2** is the result of issuing the *get ip* command via the Telnet session we kicked off in **Screenshot 1**. The New Micros carrier is fine for interfacing the RN-XV to a PC. However, we will need to get at the RN-XV's transmit and receive pins. So, it's time to move the RN-XV back over to the Rabbit cradle. From now on — as long as the RN-XV is within





■ **PHOTO 7.** We are deploying the LMX-ISM-242 development board as a receive only node. The development board can participate in a mixed LMX-ISM-242-SR/LMX-ISM-242-LR network as a receiving node, a transmitting node, or a sensor node.

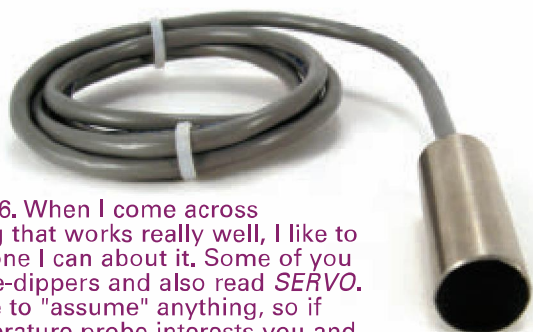
ear shot of the Linksys router — we can contact it remotely. The construction of a bridge to the gateway is complete.

## ASSEMBLING THE PAN

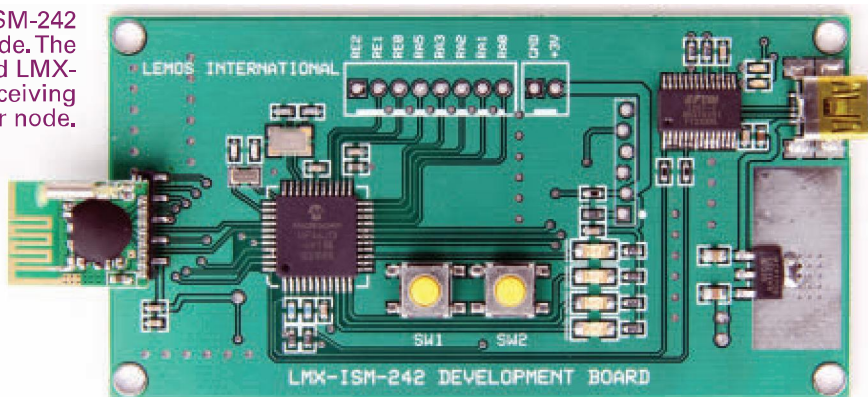
The bridge we just activated will be used to transfer sensor data from the most remote node of a two-node PAN. The receiving node of the PAN will be in RF contact with the remote PAN node and in serial port contact with the RN-XV bridge. Data from the remote PAN node will ultimately cross the bridge onto the Internet. The LMX-LR you saw in **Photo 1** is a powerful data radio. Regardless of its RF prowess, it can only do what it is told. The LMX-LR support hardware can be seen in **Photo 5**. It's linked to the PIC18F46J13 as an SPI slave. The PIC18F46J13 support hardware includes a 32.768 kHz crystal to drive its internal RTCC. Power delivery is under the control of a Microchip MCP1703 LDO voltage regulator. When the LMX-LR and PIC are sleeping, the total power consumption drops into the  $\mu\text{A}$  range. The LMX-LR circuitry is graphically depicted in **Schematic 3**.

I'm going to share a sensor with you that I wrote about in the January 2013 issue of *SERVO Magazine*. The Atlas Scientific ENV-TMP temperature sensor featured in **Photo 6** is a rugged, very low power temperature probe. The ENV-TMP's power consumption is 6  $\mu\text{A}$ , which means this temperature sensor can be powered by a PIC I/O pin. The raw temperature data captured by the ENV-TMP is easily processed by the PIC18F46J13.

Over in *SERVO*, we looked at how to use the ENV-TMP and wrote a firmware driver for it. We'll take it one step farther here. We'll power it up and transport the collected temperature data over the Internet to my laptop. Our PAN's receiving node will be realized with the LMX-ISM-242 development board. As you can see in **Photo 7**, the development board is designed to interface directly



■ **PHOTO 6.** When I come across something that works really well, I like to tell everyone I can about it. Some of you are double-dippers and also read *SERVO*. I don't like to "assume" anything, so if this temperature probe interests you and you're not a *SERVO* subscriber, get a copy of the January 2013 issue and check out what we did with it over there.



with a PC via its USB portal. We will tap into the PIC18F46J13's UART by removing resistors R7 and R8, which are in series with the UART's transmit and receive lines. Removing the resistors disconnects the PIC's UART from the FTDI USB-to-UART bridge IC. This leaves the PIC's UART transmit and receive lines free to be connected to the RN-XV. Resistors R7 and R8 are obvious in **Photo 7** as they are located just below pin 1 of the USB-to-UART bridge IC. You can also locate the resistors with the help of **Schematic 4**.

## TESTING, 0 1 2 3 ...

Okay. We have a remote LMX-LR squawking at our

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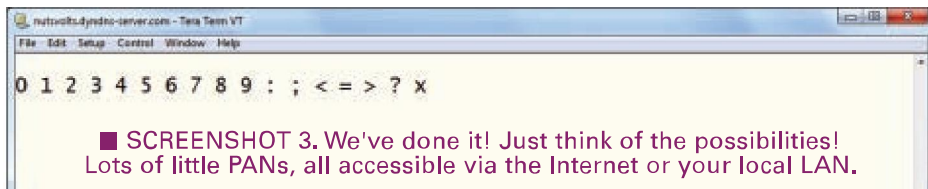
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LMX-ISM-242 development board. The development board is serially attached to an RN-XV. The RN-XV is logically attached to our Linksys router. The Linksys router has access to the Internet and the local LAN. The Linksys router has a little friend called DynDNS to allow us to locate the router despite its changing IP address. The goal is to use Telnet to contact the RN-XV and gain access to the data being squawked by the remote LMX-LR.

Take a very close look at **Screenshot 3**. The banner of the Tera Term window identifies our DynDNS server path taken by this Telnet session. The data is a test pattern generated by the remote LMX-LR.

## INEVITABLE OUTCOME

We have proven that the data from the remote LMX-LR can be accessed via the Internet using a Telnet session. So, all that's left to do is hook up the ENV-TMP. The ENV-TMP is a three-wire device. The ENV-TMP interface consists of power, ground, and signal wires. The attachment of the power and ground are obvious. The ENV-TMP's signal wire will feed one of the LMX-LR's ADC inputs.

The remote LMX-LR will transmit raw temperature data once every two seconds. The PIC18F46J13's onchip RTCC is set to generate an interrupt at a 1 Hz rate. To send every two seconds, we simply count the interrupt events. The raw temperature data is contained in a 16-bit word and is transmitted as two eight-bit bytes. Here's the code used by the LMX-LR to collect the temperature data:

```

/*****
/* GET TEMPERATURE
*****/
void getTemp(void)
{
    int1 done;
    BYTE cntnr;

    set_adc_channel(0);
    delay_ms(10);
    tempaverage = 0;
    for(cntnr=0;cntnr <10;++cntnr)
    {
        read_adc(ADC_START_ONLY);
        done = adc_done();
        while(!done) {
            done = adc_done();
        }
        tempcounts = read_adc();
        tempaverage +=
            tempcounts;
        delay_ms(1);
    }
    tempaverage /= 10;
}

```

Note that the final raw temperature is the average of 10 readings. Let's look at the actual transmission code:

```

#ifdef tx
    elapsed_secs = 0;
    do{
        if(flags.f1Hz)
        {
            flags.f1Hz = 0;
            if(++elapsed_secs >= 2)
            {
                getTemp();
                elapsed_secs = 0;
                packetBuf[1] = make8
                    (tempaverage,1);
                packetBuf[0] = make8
                    (tempaverage,0);
                xmitPacket(W_TX_PAY
                    LOAD_NOACK_CMD,
                    packetBuf,2);
                rxMode();
            }
        }
    }while(1);
#endif

```

As you can see, the *flags.f1Hz* flag is set with every RTCC interrupt. We count two interrupt events and go fetch the raw temperature data. The 16 bits of temperature data that make up *tempaverage* are broken down into two bytes and sent along their way.

The temperature transmission is picked up by the development board and processed in this manner:

```

if(flags.frxpkt)
{
    flags.frxpkt = 0;
    recvPacket();
    tempmv = make16(rxBuf
        [1],rxBuf[0]);
    tempmv *= 0.805664;
    tempC = 0.0512 * tempmv
        - 20.5128;
    tempF = (1.8 * tempC) +
        32;
    printf("%c[2;10H Temp F
        = %3.2f
        \r\n",esc,tempF);
    printf("%c[3;10H Temp C
        = %3.2f
        \r\n",esc,tempC);
}

```

The board's LMX-ISM-242-SR uses its IRQ output to inform the PIC18F46J13 that it has received a packet. The received packet is then transferred from the radio's receive buffer to the PIC's receive buffer. The pair of temperature bytes is then reunited as a 16-bit word and subjected to the ENV-TMP's conversion formula. We then take the calculated Celsius temperature value and convert it to Fahrenheit. Finally, both Celsius and Fahrenheit temperatures are sent along their way via the development board's USB portal for display.

## INFINITE POSSIBILITIES

We used an ENV-TMP temperature probe as a data generator. There is no reason why the data could not have been generated by a switch closure or motion sensor. Nevertheless, you can add the LMX-ISM-242 development board, LMX-LR, LMX-SR, and RN-XV to your Design Cycle. **NV**

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LMX-ISM-242-LR  
LMX-ISM-242-SR  
LMX Driver Firmware  
[www.lemosint.com](http://www.lemosint.com)

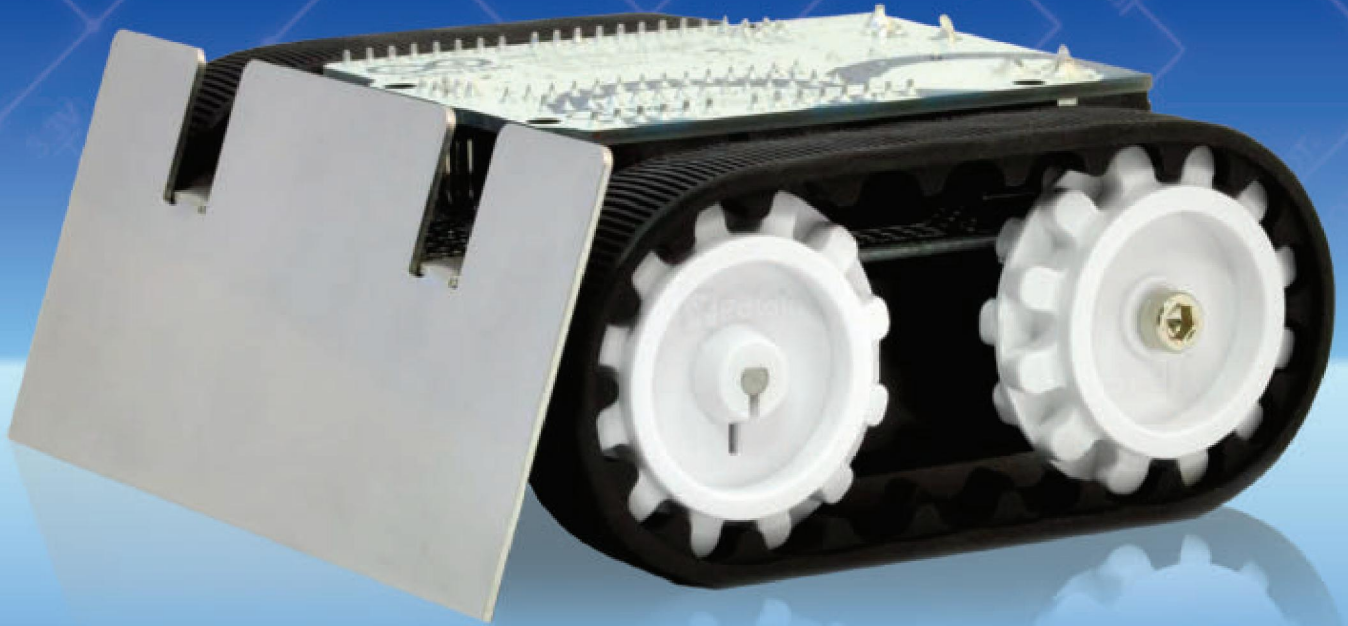
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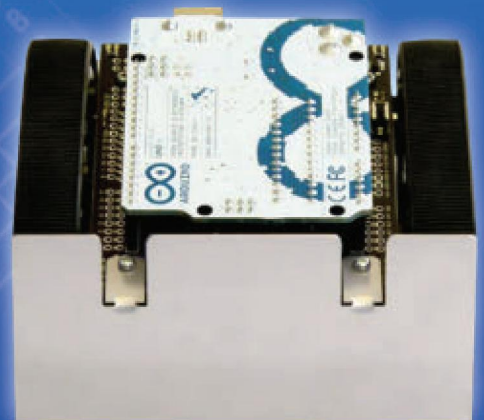
# Get a little pushy.



## Zumo

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# QUESTIONS & ANSWERS

WITH  
RUSSELL KINCAID

In this column, Russ answers questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions. Send all questions and comments to: [Q&A@nutsvolts.com](mailto:Q&A@nutsvolts.com)

## SWITCH CONTACT RATING

**Q** A rotary switch has a contact rating of five amps at 120 VAC. What would be the DC current rating for those contacts at 24 VDC? The load is resistive in both cases.

— Olie

**A** With pure resistive load, the current ratings should be the same. However, if there is any inductive load, the current rating will be reduced. The size of the gap when the contacts are open and the speed of opening will have an effect; snap action is better than a

slide or pushbutton.

You can improve the contact life by connecting a capacitor across them; 0.1  $\mu\text{F}$  to 0.5  $\mu\text{F}$  should work. For highly inductive loads, a metal oxide varistor (MOV) across the terminals will limit the peak voltage.

Motor, lamp, and capacitive loads are hard on a switch because of the high inrush current at turn-on. Motors and capacitors look like a short circuit initially, and lamps are low resistance until they heat up.

The contact material for power switches is usually silver or silver alloy. Low level (logic) switches should be gold plated to maintain low resistance. Gold plated contacts can be used for power switching, but the low level operation may be compromised if the gold is burned away by arcing.

## PADDLE KEY PROJECT

**Q** A project from the forum makes a great little key, but how much harder would it be to make a paddle key? One that has dit and dah, depending on which side you press. If you hold one side down, all you hear are dits; if you hold the other side down, all you hear are dahs. How hard is it to make something like that? Thanks.

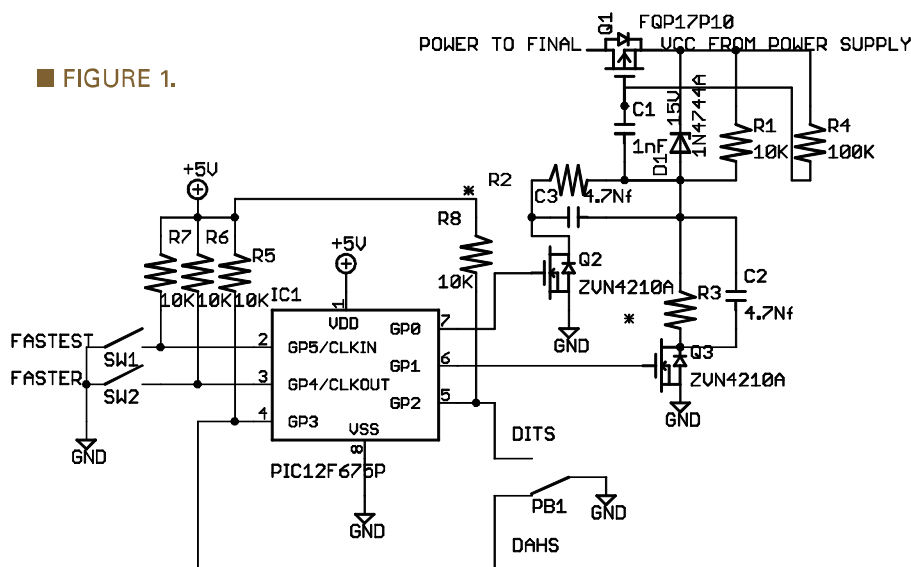
— Ronnie Reader  
(from the forum)

**A** A microprocessor can do this with fewer parts than an analog circuit using 555 timers. The downside is that the rate is fixed or — at best — selectable, depending on how many inputs are available.

The traditional paddle key (or bug as it is sometimes called) has a weight on a springy rod which is adjustable to vary the speed. The contacts are spaced differently such that dits are produced on one side and dahs on the other.

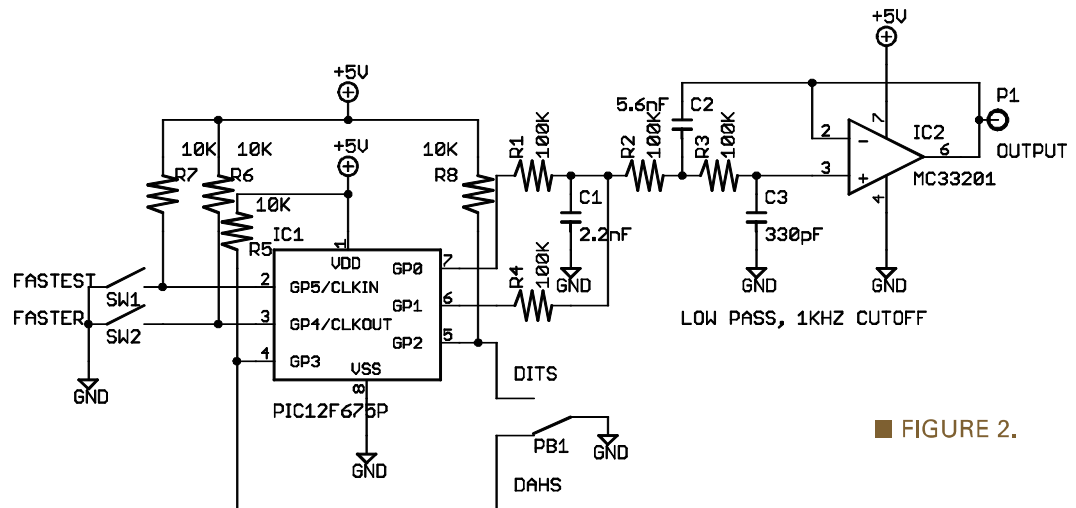
**Figure 1** is the circuit using a PIC12F675. A similar circuit (**Figure 2**) shows how to use it for code practice. The circuit has pull-ups on all inputs because the internal weak pull-up option is not working with my program; I don't know what I am doing wrong. In **Figure 1**, the transistors are rated 100V so if you are running close to that, change transistors. The zener diode limits the gate voltage and R1 provides a

■ FIGURE 1.





**Figure 3** is the program. Note



■ FIGURE 2.

LOW line, and adding REM to the  
FREQOUT line.

```

*****
' * Name       : PADDLE KEY.BAS                                     *
' * Date       : 11/18/2012                                         *
' * Version    : 1.0                                                *
' * Notes      :                                                    *
' *           :                                                    *
*****
REM device = 12F675
CMCON = 7                      'SETS DIGITAL MODE
ANSEL = 0                      'GPIO.0 TO GPIO.3 SET AS DIGITAL
    OPTION_REG.7 = 1          'ENABLES GLOBAL PULLUP
    TRISIO = %00111100        'GPIO.2 THRU GPIO.5 SET AS INPUT
GPIO = %111100                'ALL INPUTS EXCEPT GPIO.0 AND GPIO.1
WPU = %110100                 'INTERNAL PULLUP ON ALL INPUTS EXCEPT GP3
                                'WHICH HAS NO PULLUP
DEFINE OSCCAL_1_1K 1 'TO SAVE OSCILLATOR CALIBRATION
FST VAR BYTE
    FST = 2000

    IF GPIO.4 = 0 THEN FST = 750    'GO FAST
    IF GPIO.5 = 0 THEN FST = 500    'GO FASTER
START:
    IF GPIO.2 AND GPIO.3 = 1 THEN START
    IF GPIO.2 = 0 THEN DIT
    IF GPIO.3 = 0 THEN DAH

DIT:
REM USE THIS INSTEAD OF FREQOUT TO KEY TRANSMITTER
    REM HIGH GPIO.0:PAUSE 200:LOW GPIO.0
    FREQOUT GPIO.0,200,800          '200mS, 800Hz
    PAUSE FST
    GOTO START

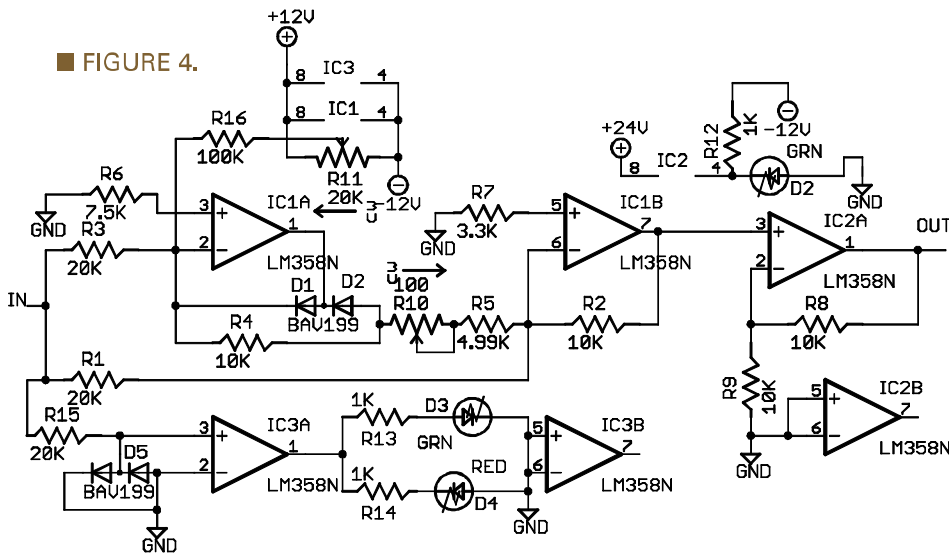
DAH:
REM USE THIS INSTEAD OF FREQOUT TO KEY TRANSMITTER
    REM HIGH GPIO.0:PAUSE 600:LOW GPIO.0
    FREQOUT GPIO.1,600,800          '600mS, 800Hz
    PAUSE FST
    GOTO START

END

```

■ FIGURE 3.

FIGURE 4.



## NEGATIVE VOLTAGE CONVERTER

**Q** I am trying to work out how I can change a negative voltage to a positive one. I have a display that will only show positive voltages, however, the input can vary from +15 through to -15. The display will fry if you try to put in a negative voltage, so I was thinking there has to be a way that you can convert the negative voltage to a positive so the display will show. I had also thought to use the input voltages to drive an

LED to show the positive or negative direction.

— Daryn Wilkin

**A** What you need is a full wave rectifier circuit; see **Figure 4**. When the input goes negative, R1 and R2 drive the output positive. At the same time, IC1A output tries to go positive but is limited by D1; D2 is reversed biased. Also, R3 is connected to virtual ground so there is no contribution to the output through this channel.

When the input goes positive, R1

and R2 try to drive the output negative with a gain of one half, but now IC1A is going negative with a gain of one half and driving R5 which has a gain of two with R2. The net result is that the output goes positive with a gain of one half relative to the input.

I am reducing the signal by half because the LM358 is rated at 32 volts max and cannot swing plus and minus 15 volts. IC2 has a gain of two, and restores the original signal level which is zero to +15 volts. The LM358 could be operated from plus 20 and minus 12, but that is at the limit of the maximum rating and is not

recommended. I am using a green LED to provide minus two volts because the LM358 cannot actually swing to ground with the negative terminal grounded.

The trimpot, R10, is to equalize the positive and negative gains. R11 is an offset trim so that zero input gives zero output. I added IC3 which switches at the zero crossing and drives a pair of LEDs which will tell you when the circuit is inverting the signal.

By the way, there's an article in the January 2013 issue by Jim Stewart on a voltage mirror that gives you -V out when you put +V in which may be of interest to you.

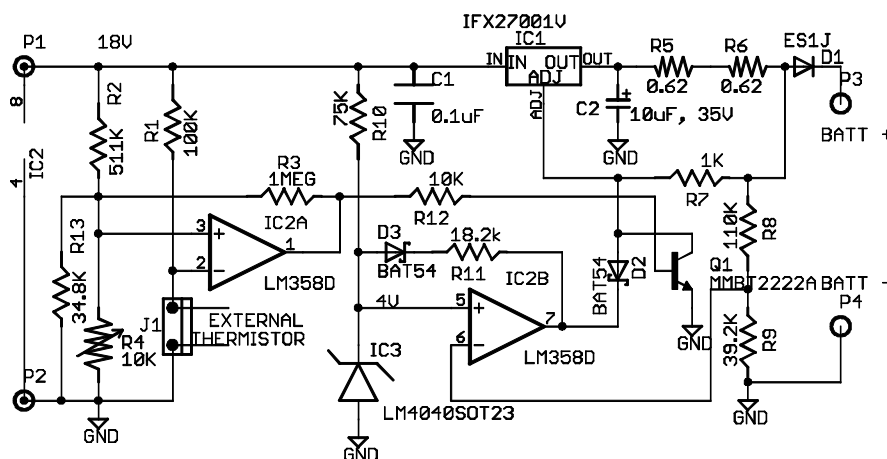


FIGURE 5.

## MAKING CIRCUIT BOARDS

**Q** Many circuits are discussed and recommended in *Nuts & Volts*, but I don't know how to make a circuit board for such circuits. Technology changes too fast! I would like to know what is actually considered the best way to make a circuit board for my project these days.

— Gim Sooner



**A** There are several options: Use pre-sensitized copperclad board that can be exposed using ultraviolet light. Contact prints are the easiest way; both positive and negative types are available. For positive types, the printed circuit will be dark and where the copper is to be etched away will be clear. The pattern should be printed in a mirror image so that the printing is close to the copper. Otherwise, the image will not be sharp. This is a good method, but I personally don't do it this way.

Use the laser transfer method. With this, the pattern is printed in a mirror image onto a material that won't stick to the copper itself, but will allow the pattern to stick when heated. Some people use a laminator to provide the heat and pressure, but I sandwich the copperclad and the pattern between two sheets of steel and put it in the oven at 400 degrees F for 10 minutes.

My oven has a preheat setting, so when it beeps I take it out to cool. I used to use sheets of glass but the glass kept breaking. You can also use an ordinary electric iron set to its maximum temperature.

The transfer material can be glossy paper, PnP Blue or PnP Wet, or Pulsar toner transfer paper. I have used all of these except for PnP Wet. The problem with glossy paper is that paper fibers get stuck in the pattern unless there is a lot of clay in it. PnP Blue works well, but if it is too hot (460 degrees F is too hot), it will shrink and smear.

I am using Pulsar toner transfer paper because it is paper based, and in my opinion, is more dimensionally stable. The paper has water soluble

```

                                BATTEMP2.TXT
*****
Eureka: The Solver, Version 1.0
Friday November 30, 2012, 8:36 pm.
Name of input file: C:\DOSPRO~1\EUREKA\HYSTCALC.EKA
*****

; calculations for a hysteresis circuit]
; this is the ckt:

;
;      ^
;  vin-----| -
; vbias--Rb-----|+ opamp-|
;                  |
;                  |---Rf-----|

;INPUT DATA:
Vouthi 15
Voutlo 0 .2
;input switching voltages, you choose
Vswhi 1.572
Vswlo 1.104
Rf 1e6

;NOTE: Vbias will normally involve a voltage divider from
;whatever reference voltage is used.
;solution:
Vbias (Voutlo*Vswhi-Vouthi*Vswlo)/(Voutlo-Vswlo-Vouthi+Vswhi)
Rb Rf*(Vswhi-Vswlo)/(Vouthi-Voutlo-Vswhi+Vswlo)

;Vref---R1---+Vbias
;          |
;          R2
;          |
;          gnd
Vref 18
k vbias/(Vref-Vbias)
R1 Rb*(1+k)/k
R2 k*R1

```

```

*****
Solution:

variables      values
k              .067205449
R1             518540.40
R2             34848.741
Rb             32654.200
Rf            1000000.0

```

■ FIGURE 6.

**Remember!**  
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glue on one side; you print on the glue side and soak in warm water to remove the paper.

The problem is that 400 degrees F is not hot enough to melt the toner, causing it to be porous. If you do melt the toner, it spreads. Pulsar has a solution called Green TRF Foil. After transferring the pattern, put a sheet of Green Foil over the pattern and heat again. The green plastic sticks only to the toner and seals it.

You can print using an inkjet printer, and then run it through a laser copier to make the transferrable pattern. Don't forget to make it mirror image. Measure the copy to make sure it is 1:1; most printers don't do X and Y to the same scale.

## NiMH BATTERY CHARGER

This is a design that I did recently that I want to share. The objective is to make a fast charger that will allow the fully charged battery to float indefinitely. Since the charge voltage is not a good indicator of state of charge, battery temperature is used to indicate full charge. The circuit is in **Figure 5**. The battery is 10 AA cells in series for a nominal 12 volts. The charge current is one amp but the charge

voltage is limited to 15 volts.

In **Figure 5**, the low dropout (LDO) regulator, IC1, is configured as a constant current source of one amp:  $I = V_{ref} / (R5 + R6) = 1.25 / (1.24) = 1.008$  amps.

If the terminal voltage of the battery should exceed 15 volts (15.6 volts at R8), the current through R8 is  $15.6 / (110K + 39.2K) = .105$  mA, and the voltage across R8 is  $.105 \text{ mA} \times 39.2K = 4.099$  volts. That is enough to turn on IC2B and reduce the current.

The thermistor, R4, monitors the ambient temperature; the other thermistor, connected to J1, is embedded in the battery. When the battery temperature rises 10 degrees C above ambient, the output of IC2A switches, turning off the current source.

Positive feedback through R3 produces hysteresis to prevent the charger from turning on until the battery cools down. The thermistors are 10K at room temperature, 1% tolerance, Mouser part #71-01C1002FP.

The design of the IC2A circuit with hysteresis proceeds this way: I want the current through R2 and R1 to be low so as not to heat the thermistor. If R1 is 100K, the current is  $18V / (110K) = .164$  mA. That puts the input (pin 2) at 1.64 volts. The other input wants to be lower at room temperature (25 degrees C) and higher



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at 35 degrees C when the resistance of the external thermistor is 6,535 ohms.

I calculate the switching voltage at 26 degrees just to be sure that switching will take place at 25 degrees. That voltage is  $18V/(109.572K)*9.572K = 1.572V$ . The low switching point is  $18V/(106.535K)*6.535 = 1.104V$ . Plugging these numbers into an equation I developed some years ago (see **Figure 6**) results in the values in **Figure 5**. The program I used is obsolete, but you could do the same thing with a spreadsheet.

The positive feedback in the IC2B circuit is just to prevent it from switching on noise, so pulling the input down 10 mV will be sufficient. When the output is high, I don't want excess current through IC3, so that is the reason for D3. I want the charger to become active again when the battery voltage gets down to 12 volts (12.6V at R8), so the input voltage can't go lower than  $12.6/(110K+39.2K)*39.2K = 3.31V$ .

At that voltage, the drop across R10 is  $18-(3.31+.5) = 14.19V$  and the current is  $14.19V/75K = .1892 \text{ mA}$ . The same current flows through R11 and the IC3 current is zero, so  $R11 = 3.31/.1892 = 17.5K$ . A standard higher value is 18.2K which will insure that the voltage is maintained to at least 12 volts. **NV**



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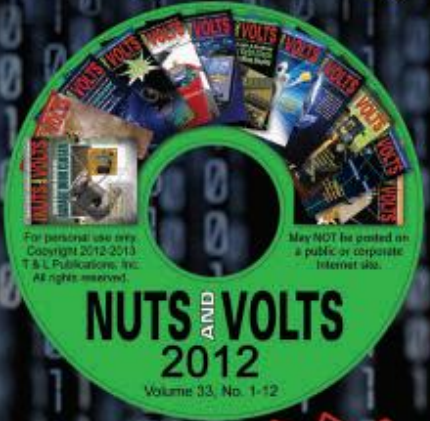


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## HEX WHEEL ADAPTORS

**A**dding to their line of ABS and foam wheels, ServoCity has two new hex wheel adaptor sets: one designed for 12 mm hex wheels, and one specifically for 17 mm hex wheels. These wheel adaptor kits allow users to convert the 12 mm or 17 mm hex drive wheels to the ServoCity 0.770" hub pattern that is found throughout their product line.

The recessed 0.770" pattern also allows users to run 6-32 socket head screws into any 0.770 hub or other component that utilizes the same pattern.

Each kit consists of two aluminum mounts, two washers, and two mounting screws. Constructed of 6061-T6 aluminum for strength and durability, these adaptors make it easy to customize mobile projects. Retail price is \$9.99/pair.



## AIR MODULE FAMILY FOR ZIGBEE AND BOOSTER PACK KIT

**A**naren, Inc., has introduced a family of four Anaren Integrated Radio (AIR™) modules designed specifically to help OEMs develop products that wirelessly communicate in compliance with the ZigBee® standard.

Based on the Texas Instruments (TI) CC2530 low power RF SoC (which operates using TI's Z-Stack™ firmware), the new family of AIR modules is bundled with AIR Support for ZigBee — a solution that includes time-saving AIR-ZNP firmware (including 30+ code examples), pre-certification to applicable global, regulatory standards, and development tools like the company's new BoosterPack for TI MSP430™ and Stellaris® LaunchPad development kits.

"Not everyone seeking to comply with the ZigBee standard is prepared for the programming and RF complexities involved with this exciting wireless protocol," says Anaren Business Development

For more information, contact:  
**ServoCity**  
Web: [www.servocity.com](http://www.servocity.com)



Manager, Mark Bowyer. "With our new AIR modules — and with the many value-added elements of AIR Support for ZigBee solutions that surround these modules — Anaren offers OEMs heading down the ZigBee path a clearer, more streamlined, and more cost-effective approach."

Features and benefits of Anaren's new AIR module family for ZigBee standard applications (part number A2530x24xxx) include the following:

#### General:

- Minimal RF engineering and ZigBee experience necessary
- Easy to program, for shortened design cycles
- Choice of integral or connectorized antenna
- Pre-certified to FCC/IC, compliant with ETSI
- Choice of range extender or non-range extender modules
- Tiny standardized footprint: 11 x 19 x 2.5 mm
- 2.4 GHz IEEE 802.15.4 compliant RF transceiver
- Excellent receiver sensitivity and robustness to interference (-95 dBm average)
- Wide input voltage range (2.2V-3.6V)
- 100% RF tested in production
- Module weight approximately 0.7 grams
- Low current consumption
- Three low power/sleep modes from 1  $\mu$ A to 200  $\mu$ A

#### Microcontroller:

- High performance and low power 8051 MCU core with code prefetch; 256 KB in-system programmable Flash; and 8 KB RAM with retention in all power modes.

#### Firmware:

- Preloaded with Anaren's AIR-ZNP firmware, based on the TI Z-Stack for the ZigBee standard (developed in cooperation with

Tesla Controls)

- Supports SPI and UART communication
- Driver library included for MSP430 and Stellaris MCUs, which abstracts functionality
- Over 30 code examples for a paired MCU (included to demonstrate functionality)

In concert with the launch of its new AIR module family for ZigBee standard applications, Anaren has also introduced a new BoosterPack featuring its new family of modules. The new CC2530 BoosterPack Kit helps OEM engineers develop wireless applications using a TI LaunchPad for MSP430 or Stellaris MCUs. Key attributes of this new BoosterPack include the following:

#### Benefits:

- Provides "out of the box" wireless connectivity for easier development of applications based on the ZigBee standard.
- Includes the AIR-ZNP firmware solution (based on TI's Z-Stack) which compresses time to market by greatly reducing the learning curve and development time.

- Provides a learning/development tool for all levels of ZigBee expertise, as well as a clear, easy-to-understand migration path from development to production.

#### Kit Contents:

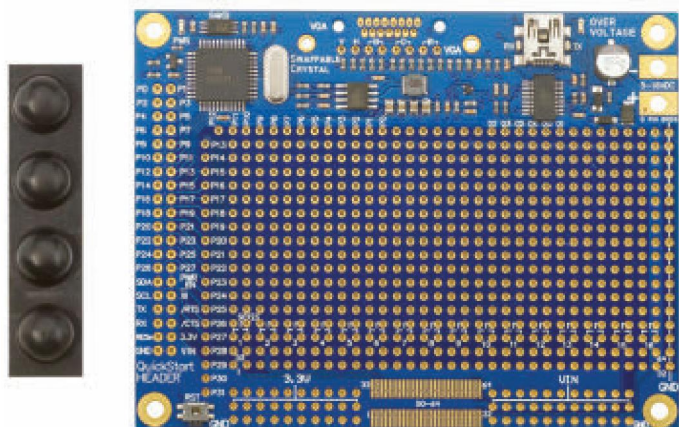
- Three A2530E24A AIR Module BoosterPacks for connection to TI's MSP430 or Stellaris LaunchPad development kit (LaunchPad not included).
- An on-board MSP430G2553IN20 Value Line MCU, pre-flashed with Anaren's AIR-ZNP firmware (based on TI's Z-Stack for the ZigBee standard).
- For Stellaris operation, simply remove the MSP430 MCUs, and load the Stellaris firmware via USB from the included CD.
- CD contains all the software, MSP430 and Stellaris drivers, application notes, quick start guide, and more to get started.
- One 2xAA battery holder for remote.



For more information, contact:  
**Anaren, Inc.**  
 Web: [www.anaren.com](http://www.anaren.com)

## PROPELLER PROJECT BOARD

The Propeller Project Board from Parallax is for projects that need a permanent home. Its low cost, feature-rich, and simple design is ideal for most any project using



the Propeller P8X32A multicore microcontroller. The core Propeller programming circuitry is built into the board, with access to all 32 I/O pins.

Features such as power and over-voltage LEDs, and well-placed labels on both sides of the board help make circuit building fast and accurate. The reset button, USB, power, and optional connectors are all set at right angles for easy access when the finished project is mounted in an enclosure. Key features include:

- Programming-ready with surface-mount Propeller P8X32A, 64 KB EEPROM, and 5 MHz removable crystal
- USB Mini-B connector for programming and power is compatible with USB charging devices.
- Large 5.75 square inch prototyping area with 580 thru-hole connections provides plenty of room for a project's components.
- Built-in pads and circuitry make it easy to add a microSD card holder and VGA connector.
- SOT-23 pads and custom-designed 64-pin SMT pads accommodate a wide variety of IC packages.
- 40-pin header accepts add-on boards made for the Propeller QuickStart.

The retail price is \$24.99.

For more information, contact:

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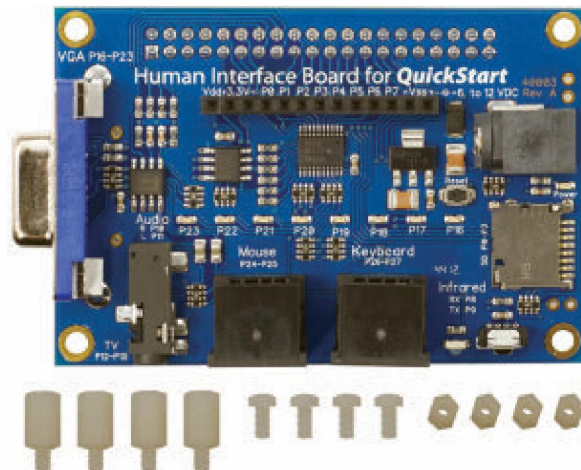
## SERVO MOTOR CONTROLLER

Images SI, Inc., has released a updated servo motor controller that provides smoother servo motor

response. The SMC-01 is a manual controller for a single servo motor by way of an onboard potentiometer. The heart of the SMC-01 is a PIC12F683 microcontroller. The potentiometer connects to the microcontroller and proportionally

## HUMAN INTERFACE BOARD

The Human Interface Board also from Parallax brings advanced functionality to the QuickStart development platform. The Human Interface Board stacks directly on



top of the QuickStart development platform, creating a minimal footprint for both boards.

With multiple audio and video outputs, and keyboard or mouse inputs, as well as a microSD card socket, the Interface Board can add an interactive interface to any project. Where applicable, it uses the same I/O pin assignments as the Propeller Demo Board peripherals.

Like the QuickStart development platform, the Human Interface Board is an open-source hardware design, so all design files — including layout, schematics, and firmware — are available under licenses that allow free distribution and reuse. The Human Interface Board's design can be incorporated into new applications royalty free and without a non-disclosure agreement. Key features include:

- Multiple audio and video outputs for application flexibility.
- Two PS/2 ports for either two keyboards, two mice, or a mix with one keyboard and one mouse.
- Infrared transceiver for remote control and communications.
- Expandable storage for up to 32 GB of data storage and retrieval.

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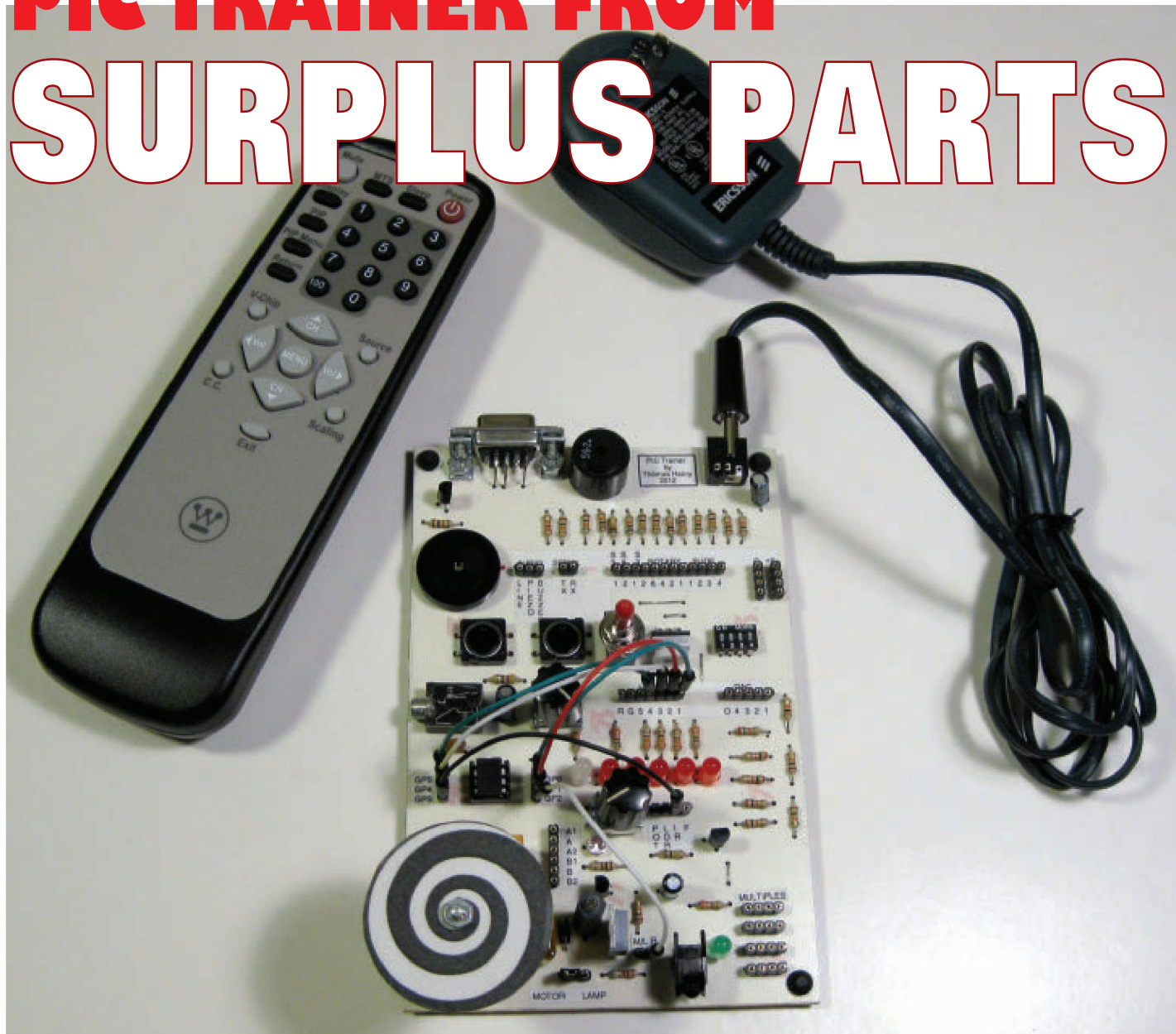
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# BUILD YOUR OWN PIC TRAINER FROM SURPLUS PARTS

By Thomas Henry



Not long ago in an electronics forum on the Web, a question popped up on how to build a certain complex device. Besides several helpful responses, there was one that struck me as missing the point altogether. In particular, the respondent said something like, "Why build it when you can buy a commercial one?" Of course, in some circumstances our time is worth more than the cost of a purchase. However, if our goals include learning something new as we go along, taking pride in what we've built with our own hands, or even saving a little money at the expense of time, then there's still much satisfaction to be found in our craft. Apparently, I'm not the only one who feels this way because the respondent took some heat.



If you too relish the feeling of accomplishment in building a personalized and/or customized project, then have I got a deal for you! This article demonstrates how to assemble a versatile PIC trainer using only surplus parts. Belying its humble origin, this really is an open-ended and high quality learning tool. In the brief time I've been using it for my own education, I've already written code for and whipped together a number of fascinating circuits. Thanks to the breadboard-like nature of the trainer, it's a snap to go from a theoretical concept to a working project in a matter of minutes. Plus, the circuit has been carefully designed to be virtually indestructible, making it suitable for even the most careless of learners.

Sure, you may be able to find commercial units that'll do the trick, but by building your own from scratch you'll be enhancing the learning experience while simultaneously arriving at a tool you can put your own personal stamp on. Best of all, this PIC trainer is easily customized to your own purposes, and by taking advantage of what's currently in your junk box it will hardly dent your wallet.

## A Tour of the Trainer

So, what can you do with it? **Figure 1** gives an overview of the components that make it up. Fitting on a single 4" by 6" circuit board, applications can be broken down into six categories:

- Visual indicators
- Switches
- Analog and audio output
- Analog input
- Higher power devices
- Serial input and output

Let's take a brief tour of what's available on the PIC trainer. The unit is configured around the inexpensive and easy-to-use PIC12F683

microcontroller. This is an eight-pin device, with a maximum of five outputs available at any given time. For visual displays, there are five red LEDs. Additionally, there is a single bicolor LED which can show red or green, or even orange if you alternate the signal applied to it. Lastly, I also threw in an ordinary incandescent lamp just to demonstrate how easy it is to control higher current devices.

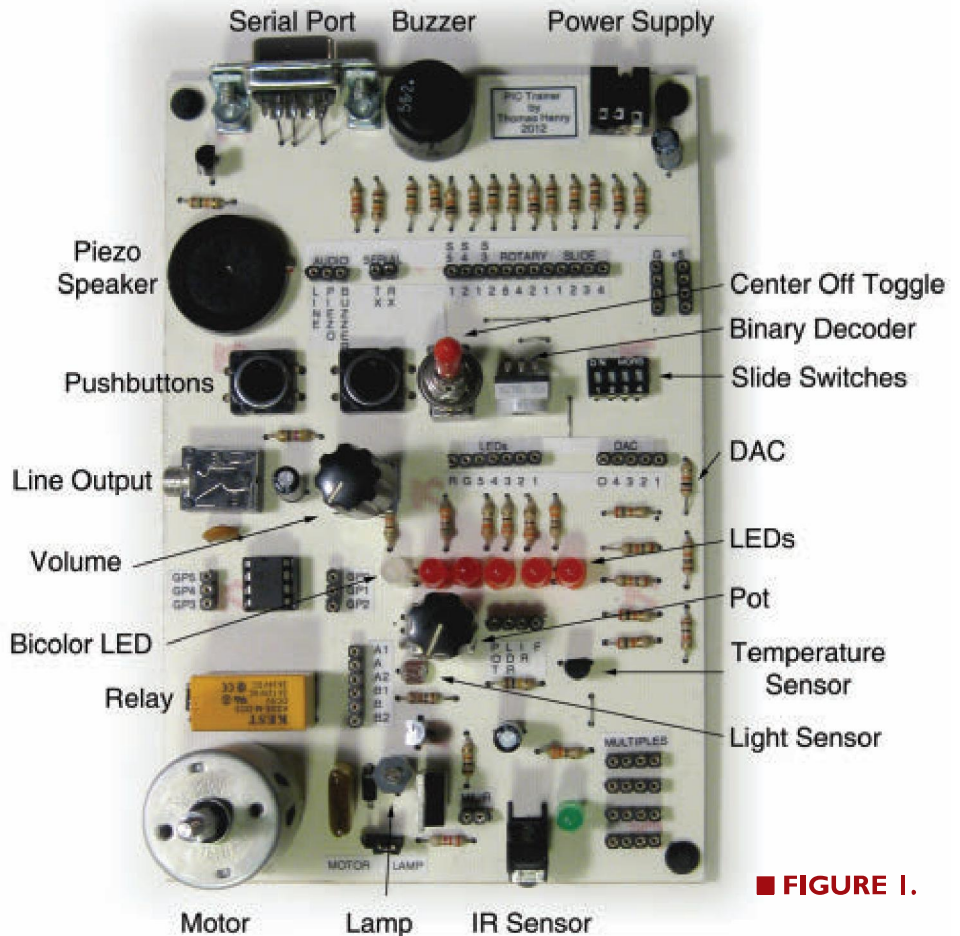
You've got a lot of options for switches, starting with a pair of momentary pushbuttons. There are also four slide switches for set-and-forget operations. Next is a center-off SPDT toggle switch. This is great for demonstrating how software can sense three states using only two port pins. Last is the fascinating four-bit rotary switch. This neat apparatus spits out binary numbers from zero to 15.

There are three main options for audio output. First off is an

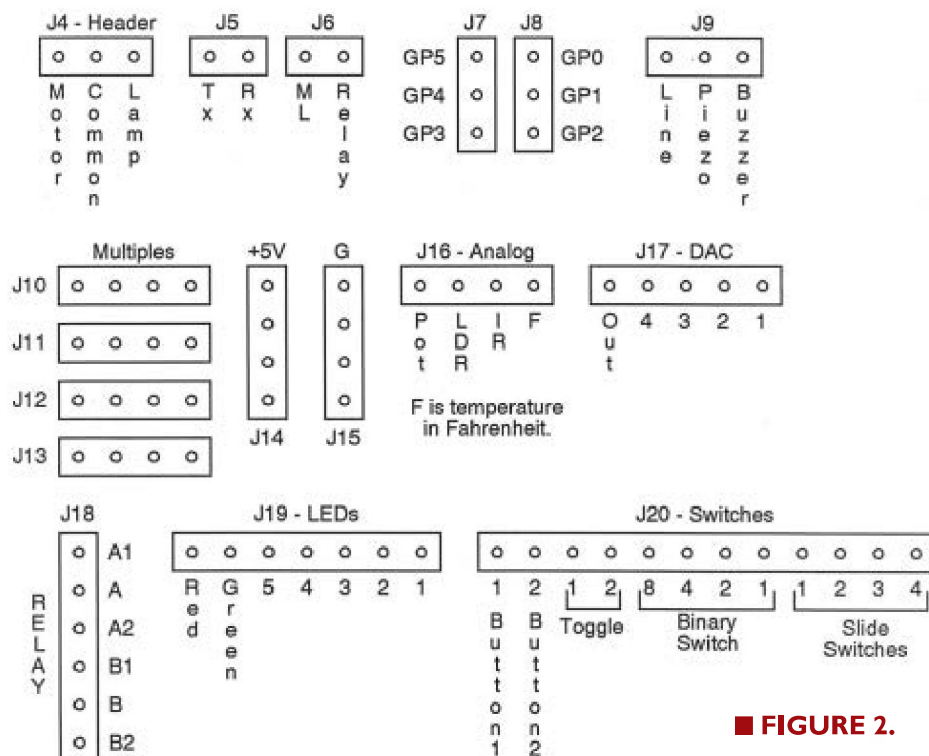
electromechanical buzzer for alarm applications. The piezo speaker can be used to create more musical effects. If the piezo isn't loud enough to suit you, then there's a line output jack with associated volume control. This can feed an external amplifier if desired. The circuit is designed so it can also safely drive an outboard loudspeaker directly.

A four-bit digital-to-analog converter (DAC) is available for experimentation, as well. I put this in primarily for demonstrations on an oscilloscope. If you're driving something with a lesser impedance, then you'll want to buffer the signal.

Our trainer is no slouch when it comes to analog input, either. Remember that the PIC12F683 has built-in analog-to-digital conversion (ADC) facilities so it's easy to read the included temperature and light sensors, as well as the uncommitted potentiometer. The really neat thing



■ FIGURE 1.



■ FIGURE 2.

is the infrared (IR) sensor. This responds to the codes emitted by an ordinary television remote control.

It is often the case that a microcontroller is expected to tame higher power devices. For ventures along these lines, I've included a

DPDT relay and a DC motor. With regard to the latter, the ever versatile PIC12F683 also includes pulse width modulation (PWM) capabilities, so it's a snap to efficiently control motor speed this way.

Finally, for communicating with

PCs and other external devices, there is a standard DB-9 type connector for sending and receiving data by means of the RS-232 protocol. If your computer has a serial COM port, then you can connect it up directly. Otherwise, you'll need to attach one of those cheap USB-to-COM connectors.

Interconnecting the various subcircuits is fast and easy, thanks to the SIP sockets. These provide openings much like those found on a solderless breadboard. You'll be able to patch together whatever you want in a matter of seconds. I got a handful of snazzy color-coded flexible jumpers from Amazon.

Figure 2 shows the socket arrangements. There are even a few extras thrown in for use as multiples and, of course, the +5V and ground lines are available, as well. By the way, the motor and lamp share the high power Darlington transistor, so there is a male header (J4) which lets you choose which one you want.

Simply slip one of those little jumper clips over two adjacent pins to make your selection. To keep everything straight, I printed out labels and affixed them to the printed

## PARTS LIST

### ITEM DESCRIPTION

All fixed resistors are 1/4 watt, 5% values.

R1	47Ω
R2	100Ω
R3-R9	330Ω
R10	2.2K
R11-R23	4.7K
R24-R29	10K
R30, R31	10K potentiometer (LPC-10K)
R32-R36	20K
R37	22K
R38	100K

Capacitors are 10V or better.

C1	0.1 μF disc
C2	0.22 μF mylar
C3	1 μF electrolytic
C4	4.7 μF electrolytic
C5	10 μF electrolytic

### Semiconductors

D1, D2	1N4001 rectifier
D3-D7	Red LED

D8	Green LED
D9	Bicolor LED (LED-6)
Q1, Q2	2N3904 transistor
Q3	TIP112 Darlington pair (TIP112)
IC1	PIC12F683 microcontroller
IC2	Temperature sensor (LM34DZ)

### Switches

S1	4PST DIP switch (DWS-4S)
S2	Four-bit binary switch (RS-162)
S3	SPDT center-off toggle (MTS-5)
S4, S5	SPST pushbutton (MPB-223)
RELAY	5V/130Ω DPDT relay (RLY-625)

### Jacks and Sockets

J1	2.5 mm DC jack (DCJ-17)
J2	3.5 mm stereo audio jack (SMJ-6)
J3	Female D-9 jack (DB-9S)
J4	Three-pin male header (SHS-32)
J5, J6	Two-pin SIP socket
J7-J9	Three-pin SIP socket
J10-J16	Four-pin SIP socket
J17	Five-pin SIP socket
J18	Six-pin SIP socket
J19	Seven-pin SIP socket

J20	12-pin SIP socket (See text for information on SIP sockets.)
-----	---

### Other Components

B1	5V/30 mA buzzer (SBZ-582)
B2	Piezo speaker (PE-54)
IR	Infrared receiver (see text)
LAMP	5V/125mA lamp (LP-715)
LDR	CdS LDR (PRE-24)
M1	5V/60 mA DC motor (DCM-406)

**Miscellaneous:** +5V regulated wall wart (PS-513), power plug (DCLID), TV remote control (REM-4), circuit board, IC socket, solder, wire, rubber feet, etc.

The PIC12F683 is available from many supply houses, including SparkFun Electronics ([www.sparkfun.com](http://www.sparkfun.com)), Jameco ([www.jameco.com](http://www.jameco.com)), and Mouser ([www.mouser.com](http://www.mouser.com)).

Most of the other parts are available from surplus houses. For example, the All Electronics ([www.allelectronics.com](http://www.allelectronics.com)) stock numbers for the more unusual items are shown above in parentheses.



circuit board (PCB).

As you can see, there's a lot going on within our PIC trainer. In fact, it seems so fancy that I should

probably remind you once again that the whole shebang (apart from the inexpensive PIC12F683) is built with surplus parts. Just don't let the

discounted nature of the trainer deceive you. It's possible to do some serious work with this high quality beast.

## First Step: Understand It

Let's turn our attention to how the PIC trainer works by wending our way through the schematic in **Figure 3**. You'll want to socket the PIC12F683, of course, as well as make provisions for connection to its pins.

Notice that all six of the I/O port lines are brought out to sockets J7 and J8.

The LEDs have the typical current-reducing resistors in place, R3 through R8. The red ones simply connect to ground, while the bicolor LED makes both legs available.

Turning to the serial port, J3, you'll notice the series protection resistor, R37. This is needed since RS-232 signals can swing as much as 12 volts — positive or negative. R24, on the other hand, is simply a pull-down to keep the sensitive input line from floating.

As for the switches, each has a pull-up resistor, R11 through R22. These ensure that the PIC isn't looking at input lines bobbing about in an indeterminate state. There's a lot of repetition here, but really it's nothing more than 12 switch elements and 12 pull-ups.

Let's check out the audio stuff next. Keep in mind that a typical port line on a PIC can source or sink no more than 10 mA. For that reason, the electromechanical buzzer is buffered by transistor Q1. The piezo is a low current device, however, so it can connect to the PIC directly.

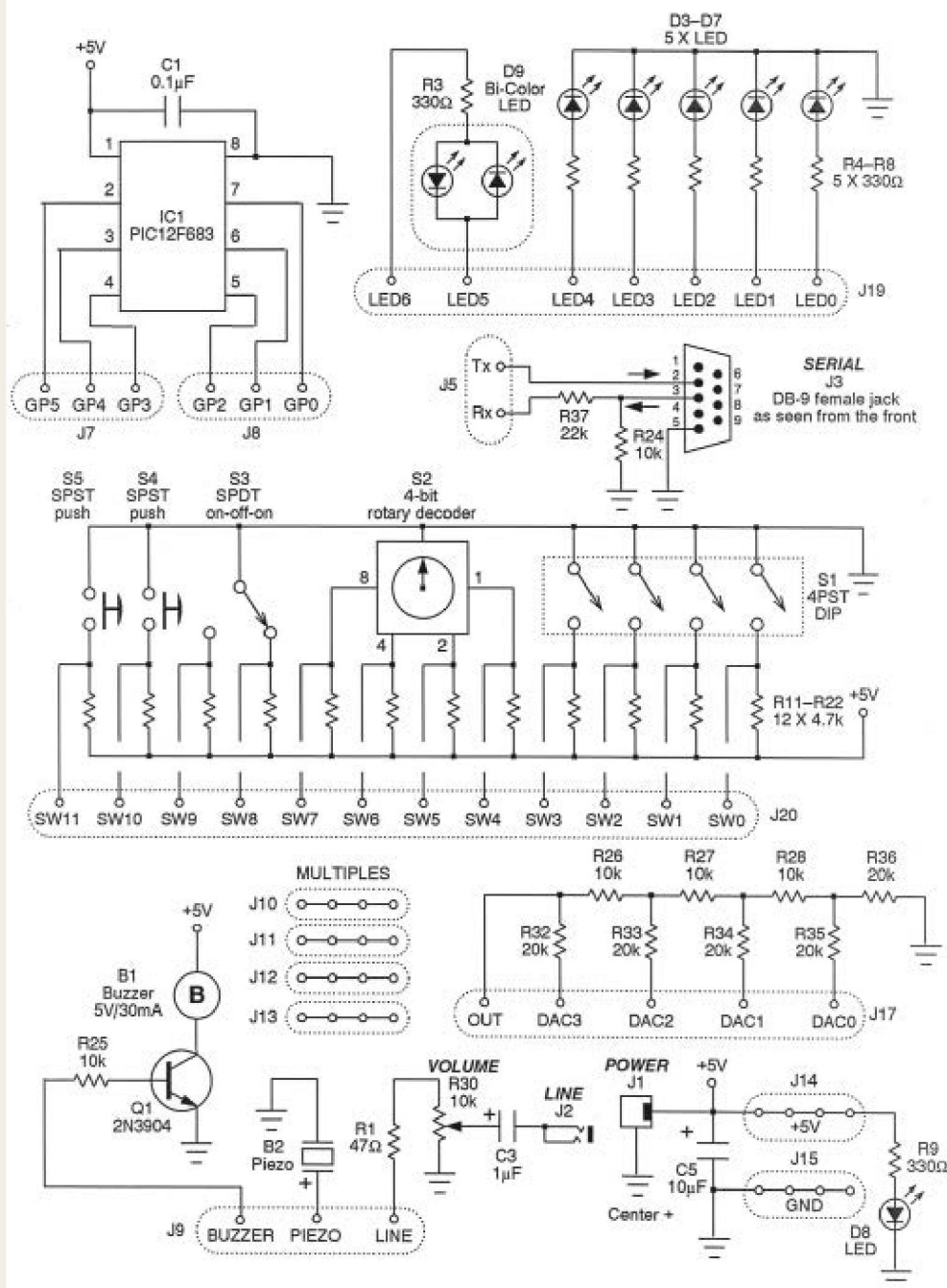
The line output features a 10K volume control and blocking capacitor C3. Easy to miss is series resistor R1. With this in place, it is

safe to connect an ordinary 8Ω loudspeaker. The line output may also go to an external amplifier if desired.

The DAC is the trusty old R-2R affair, so called due to the values of the resistors employed. Remember,

it's not buffered so don't expect to drive any low impedance circuitry directly without some additional components.

Finally, power is supplied via a regulated +5V wall wart. J14 and J15 make the supply voltage available for



■ FIGURE 3.

## Second Step: Collect the Parts

Many of the components in this circuit are commonplace; things like capacitors, resistors, and the like. You probably already have the bulk of them in your junk box but some of the more unusual items might give you pause. I had no trouble outfitting my trainer using surplus parts. In fact, one shopping trip did the trick. I basically got everything I needed for the entire project from All Electronics. If you'd like to follow suit, I have provided stock numbers in the **Parts List**. Do keep in mind, though, that most of these items are available from a variety of surplus dealers. Here are a few comments on several of the parts.

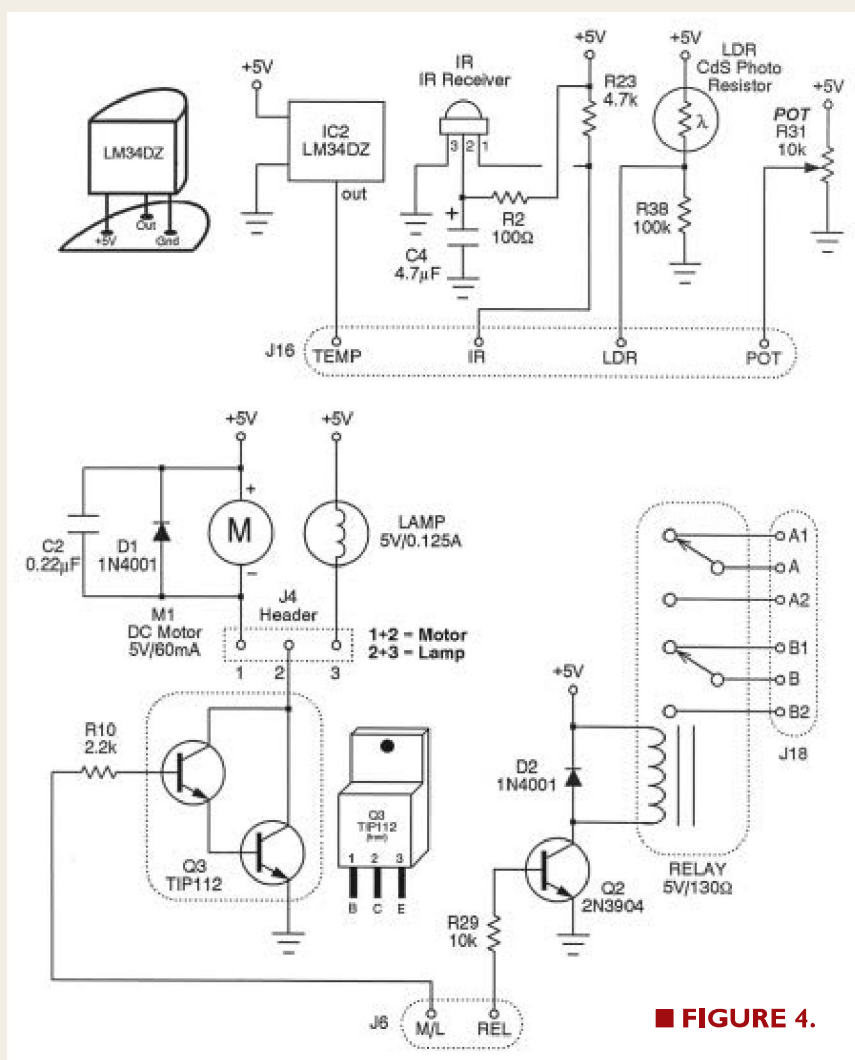
The PIC trainer is powered by a regulated +5V wall wart. The one I stumbled on, however, had a weird connector so I clipped it off and replaced it with a standard 2.5 mm barrel type. This mates with PCB-mounted receptacle J1. A green LED, D8, indicates power-on status.

The IR sensor in the trainer expects to read a signal from a Sony type remote control unit. I found just such a hand controller at All Electronics for two bucks, and it works very well. Alternatively, you could use one of those universal remotes, as long as it puts out the Sony codes.

Now about the sensor. It's the nature of the surplus business for stock to change without warning. I designed this circuit around a Vishay TSOP2138 IR sensor I purchased earlier. However, I'm now seeing one manufactured by Sharp that is probably a decent substitute. It's possible the pinout is different, so be sure to check the datasheet before building with it.

Just so you know, most of these inexpensive IR sensors use a standard 38 kHz carrier frequency, so even if the pinout changes the firmware will remain much the same.

The sockets (J5 through J20) actually all come from the same



■ **FIGURE 4.**

outboard components.

Now, turn to **Figure 4** for the remaining circuitry. At the top, you'll find the analog sensors. Temperature chip LM34DZ is a no-brainer; just hook it up directly and away you go! The output is already scaled to Fahrenheit, so the source code required for the microcontroller is very short and sweet.

The light sensor is a cadmium sulphide photoresistor, or light dependent resistor (LDR). This is tied in series with R38 to create a voltage divider. The uncommitted potentiometer, R31, is also a voltage divider. Recalling that the PIC12F683 contains ADC circuitry, then it's equally easy to take a light reading or peg the position of the pot.

As for the IR sensor, be sure to double-check the pinout for whatever unit you're using. In my case, pin 2 is hot while pin 3 is ground. Notice R2 and C4 which filter the supply voltage somewhat. The output is pulled up by resistor R23 and is finally made available to socket J16.

The relay is a fairly high powered device, so it's controlled by means of transistor Q2. Rectifier D2 snubs any reverse-EMF, protecting both the transistor and the microcontroller.

The motor and lamp are also higher powered devices. In this case, we'll use the even beefier Darlington transistor, Q3. The male header, J4, lets you choose whether the transistor controls the motor or the lamp.

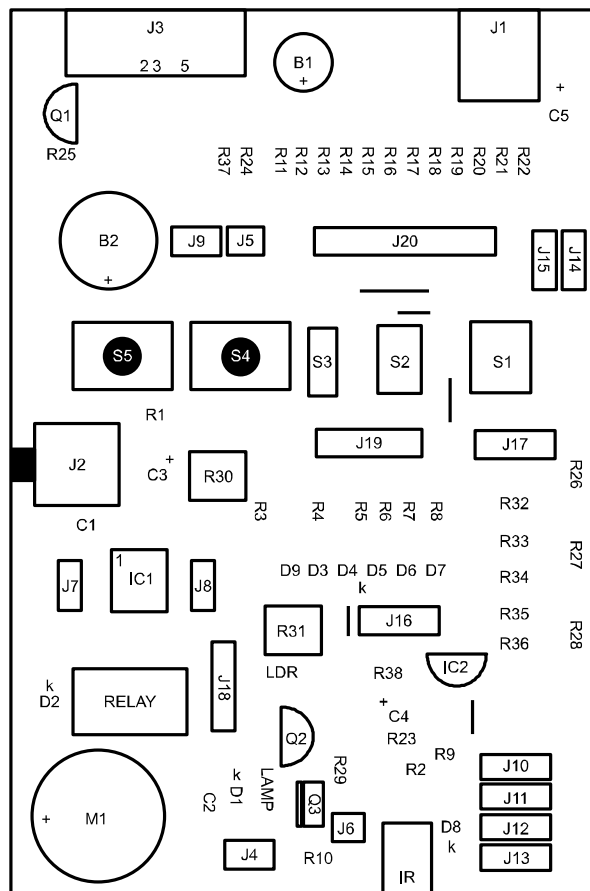


source: a snappable SIP affair. Essentially, this is one long row of sockets that you simply snap off a portion of to create the desired size. A pair of needle-nose pliers helps make a clean break. The PIC12F683 is a common microcontroller costing no more than a few bucks, so why not pick up a couple while you're at it. The **Parts List** mentions several places where it is available.

## Third Step: Build It

There is absolutely nothing critical about the trainer circuitry, so feel free to build it on perfboard by hand if desired. I prefer PCBs myself, and it was simple enough to work up the pattern. I transferred it to a copperclad board with nothing more than a small travel iron (for pressing clothing). The etching was done in a Tupperware tank right in the kitchen. It's a simple homely affair, but in less than a half hour I churned out a decent board. The drilling took place in the workshop, of course, using a Dremel drill press. Don't forget to slip on a pair of goggles before starting.

Since we're using surplus parts, you might find (like I did) that occasionally you'll have to clip an extraneous tab off of a component or drill out a bigger hole to accommodate it on the PCB. It's not a big deal — essentially you're customizing as you go along. **Figure 5** shows the parts placement guide for my rendition.



■ FIGURE 5.

There are five jumpers, denoted by line segments. The letter k denotes cathode.

## Final Step: Use It!

Now comes the fun part — actually putting it in motion. Remember, this is a trainer so you're supposed to be learning something. The thing is so much darn fun to use, though, that the education comes along gratis.

I've provided some sample projects (written in the free open source Great Cow Basic language which is perfect for beginners) to get you started. You'll find the source code at the article link. Just as a teaser, you'll see how to:

- Log temperatures minute by minute and send them to a PC.
- Control motor speed with the television remote.
- Play a bit of music.
- Do some blinky LED things, of course.

If you really want to learn about microcontrollers, then jump in and try your hand at a custom circuit. The sky's the limit with your very own PIC trainer built from surplus. **NV**



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# THE WIDE RANGE PULSE GENERATOR

By Sam Gailbreath  
and Rick Peterson

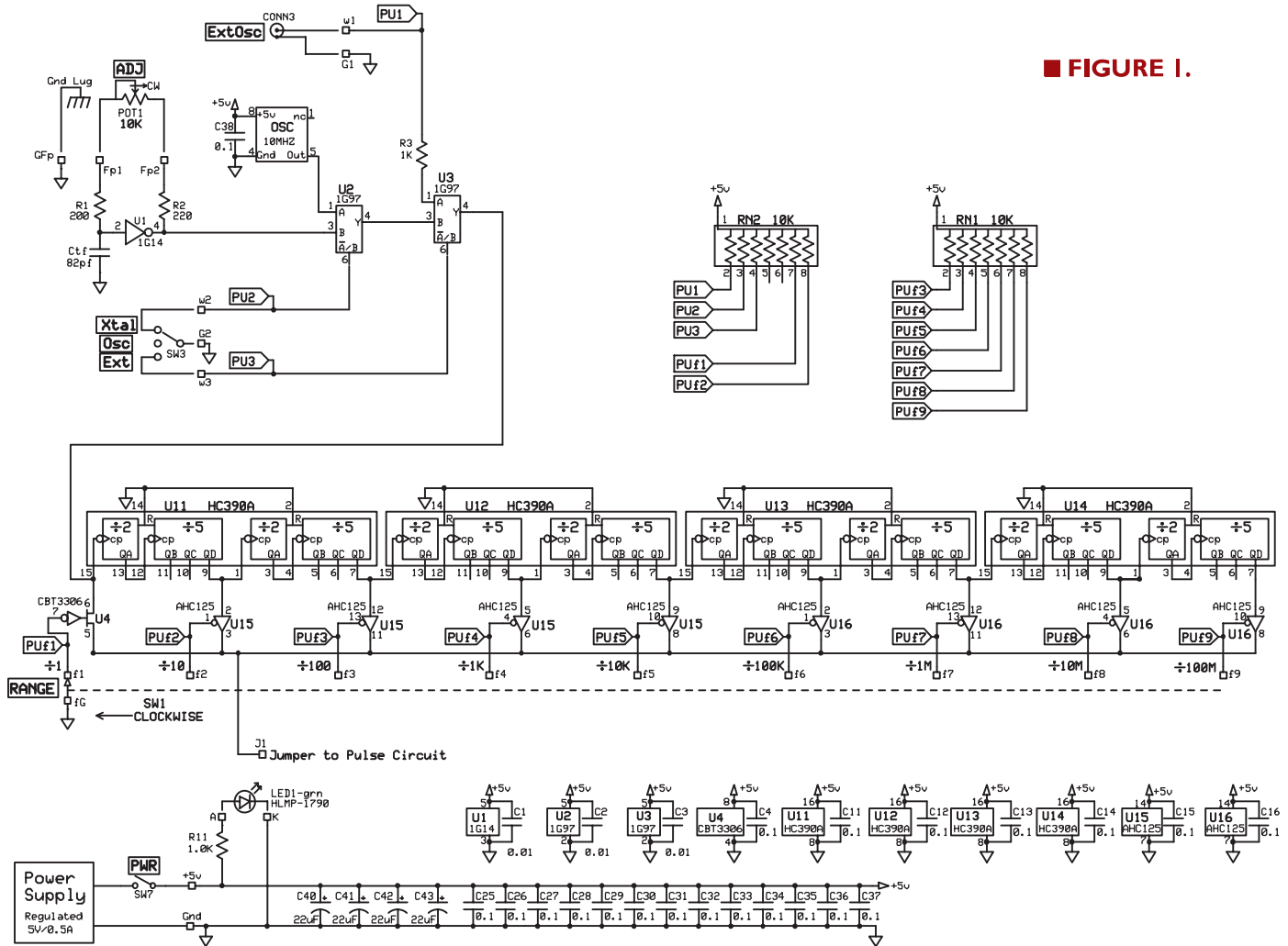


**If you are an electronics hobbyist, you often need to generate pulses and logic levels to check out the operation of your circuit before completely finishing the project. If you breadboard a circuit to see if your idea will work, you need signals to check its operation. If your circuit interfaces with the external world, you need to simulate inputs during development. If you experiment with electronics, a pulse generator is a handy tool.**

**W**hen I started as an electronics hobbyist, my first design was a digital speedometer. I made a pickup that produced a pulse each time the drive shaft made a revolution. I quickly realized that unless my wife drove me up and down the street while I worked on my circuit in the back seat, I needed something to simulate pulses on the workbench. I got through the speedometer project with a 555 timer and a trimpot to simulate the driveline pulses, but my very next project was a general-purpose pulse generator.

This project is an upgraded design that incorporates features I found over the years to be most helpful to an electronics hobbyist. It is an instrument with real knobs that can be quickly and easily adjusted — without soft keys or layered menus.





■ FIGURE 1.

## Experimenter's Wide Range Pulse Generator

This design is simple and straightforward, using oscillators followed by digital dividers; take a look at the schematic that is shown in **Figures 1** and **2**. The dividers provide a method of changing the frequency and pulse width ranges with static digital signals instead of capacitor switching, which is the classic method.

Static digital signals are relatively insensitive to wire length and routing, and eliminate layout headaches as well as tolerance problems that come with the

switching of capacitors.

As implemented, the circuit achieves a nine decade range providing frequencies from approximately 20 MHz to 0.01 Hz, and pulse widths from approximately 25 nsec to 100 sec.

The only signals that are sensitive to wire routing are those that adjust the oscillators. The potentiometer leads that go to the Schmitt trigger oscillators must be kept short and neat. Additionally, the circuitry must be enclosed in a metal (conducting/shielding) enclosure to prevent external fields from interfering.

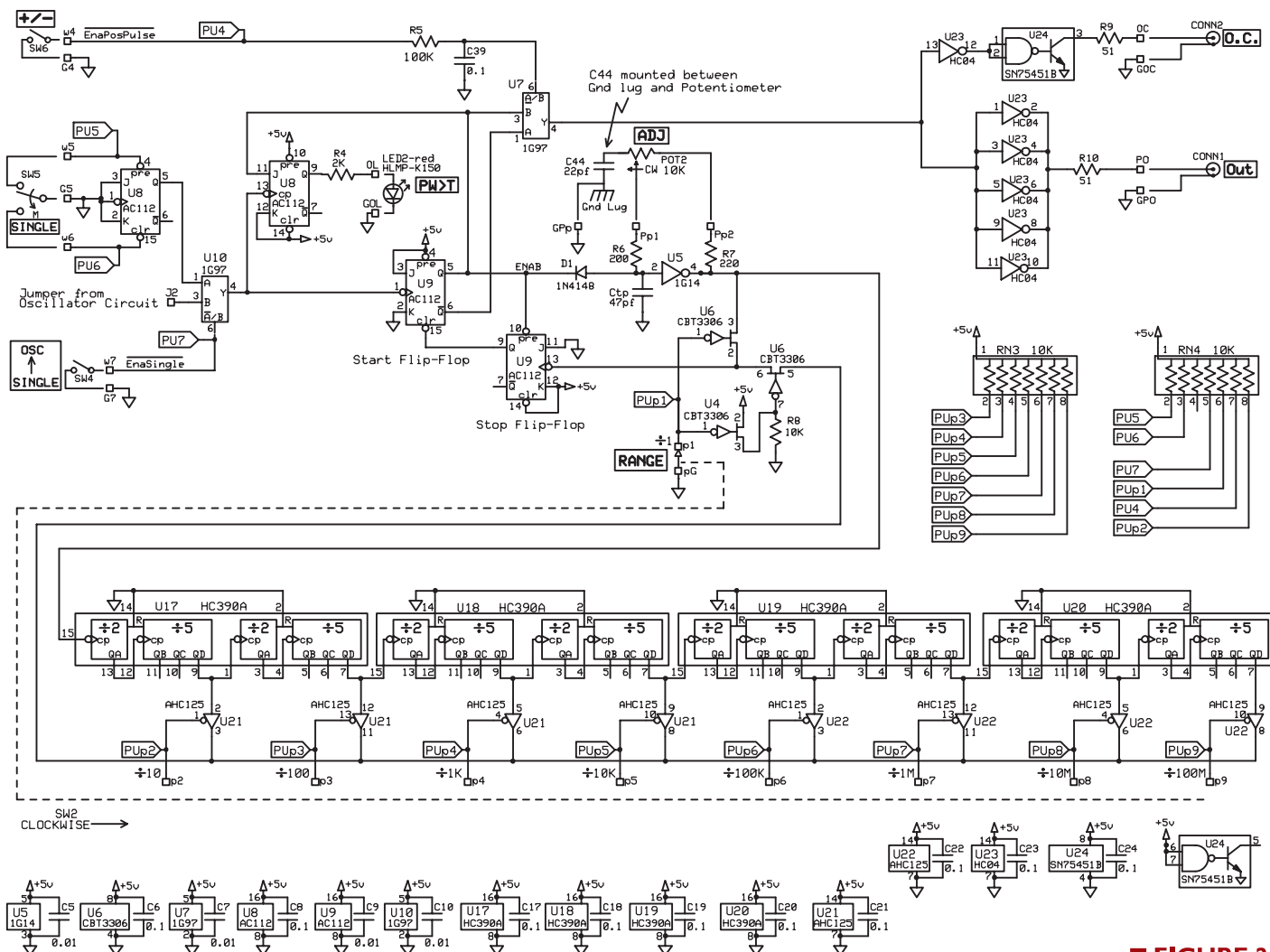
There are two outputs. In addition to a driven 0V to 5V logic level signal output, an open collector

output has been implemented. The open collector will require the circuit under test to have a pull-up (to get the high logic level) which will allow the output to match any logic level voltage (e.g., CMOS running at 9V).

An open collector also allows the power supplied to the circuit being tested to be turned off without disconnecting the pulse generator since no current is fed to the test circuit from the open collector output. The open collector is just about the only output I ever use.

To keep things simple, power for the pulse generator is supplied from a regulated 5V wall adapter.

One of the goals of this project was to get an introduction to surface-mount devices (SMD). Some very



■ FIGURE 2.

cool logic functions are only available in SMD packages. The use of SMD parts was minimized to keep soldering on the printed circuit board (PCB) manageable.

To gain experience with different sizes of SMD components, SOIC and SOT packages were chosen. SMD resistors or capacitors were not used because they are very hard to solder, and not necessary to effectively implement the design.

This pulse generator is a complete design and does not need any additional circuits to provide many years of useful service.

It can also be expanded by the experienced hobbyist who might add features such as variable output amplitude or a 50 ohm cable driver.

## The Circuit

The frequency and pulse width oscillators are classic Schmitt trigger logic gate oscillators where the capacitor charges and discharges between the thresholds of the Schmitt trigger input. The charge time is adjusted by the external potentiometer.

In the frequency section, the Schmitt trigger oscillator is multiplexed with a crystal oscillator and an external input to allow the user freedom to generate signals as needed for different kinds of troubleshooting. The selected frequency is then applied to the decade divider string.

A specific decade is selected by grounding the corresponding enable line on one of the AHC125 tri-state buffers. Using the crystal oscillator, an accurate frequency every decade from 10.00 MHz to 0.10 Hz can be selected.

The pulse width section is similar but includes a pair of flip-flops (U9) and a diode (D1) to start and stop the oscillator. The pulse width oscillator is stopped when the input to the Schmitt trigger (U5) is held low by grounding the cathode of D1, and is allowed to run when the cathode of diode D1 is held high.

When an edge from the frequency generator clocks the "start" flip-flop high, the oscillator starts. When the selected output of the



divider chain clocks the "stop" flip-flop low, the start flip-flop is cleared and the oscillator stops. When the output of the start flip-flop goes back low, the stop flip-flop is preset high, and the circuit is ready for another cycle. The pulse width is the time the oscillator runs before feedback from a selected divider stops it.

In the narrowest pulse range, bus switches (U6) are used to route the oscillator output to the stop flip-flop without propagation delay, and to isolate it from the capacitance of the divider output bus so that narrower pulses can be obtained.

A flip-flop (U8) is used to detect that the pulse width has been set greater than the period of the frequency and may be causing an erratic output. The other half of U8 is used as a switch debouncer for the "single pulse" momentary switch.

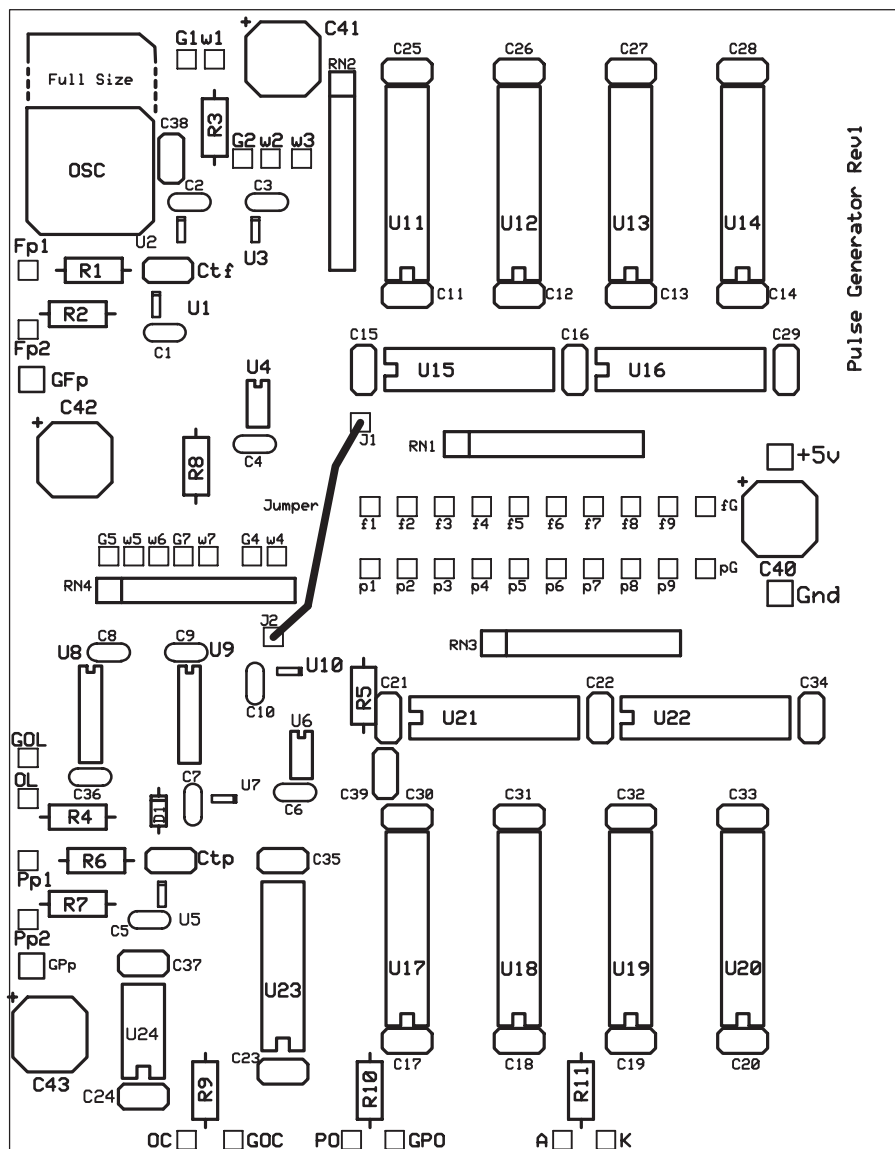
The outputs are not intended to be instrument-grade 50 ohm cable drivers. They will, however, do a reasonable job of supplying logic level signals.

## Component Selection

The ICs in the oscillator and pulse width start/stop circuits were chosen for high speed. Using other parts may not present a problem, but be aware that substituting any of these may result in lower top end frequencies and wider minimum pulse widths.

Also, the first divider IC (U11 and U17) should be the "A" suffix type specified in order to guarantee operation at the higher frequencies under worst case conditions. Note that the pin numbering on the SOT packages is different for different logic functions.

The potentiometers and rotary switches were selected to be functional at low cost. A true "logarithmic taper" pot would be nice but they are expensive, so an audio pot was chosen. An "audio taper" approximates a log curve with straight lines. The open collector



■ PCB parts placement guide.

peripheral driver (U24) was chosen for speed, as well as for high current and voltage. It is rated at 30 volts and 300 mA, making it almost indestructible in normal use.

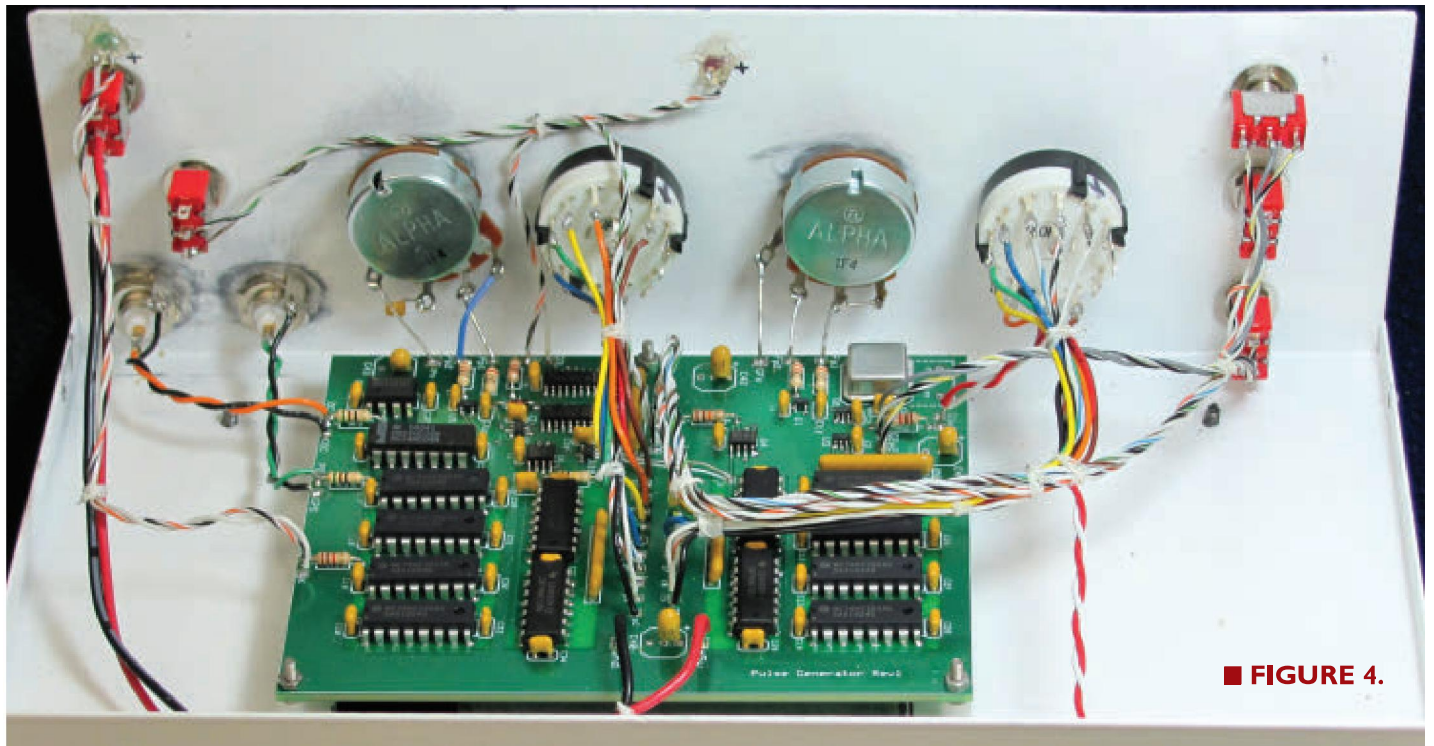
The "pulse out" IC (U23) was chosen for high current drive and speed. The resistor in series with the output is to limit the rise and fall times, and minimize ringing on the output pulse. If you don't need the higher frequencies and the narrower pulse widths, a slower part such as a C04 is worth considering since the slower rise and fall times are less likely to cause some kind of trouble.

The single pulse momentary switch was chosen to be a toggle type so that there would be tactile feedback from the switch when generating a single pulse. Most panel mount pushbutton switches do not have tactile feedback and I find that annoying. (Did it make contact or not?)

Also, pushing in on a switch tends to move an instrument while pushing down on a toggle keeps it in place. Please use any type of momentary switch you like. Acceptable and sometimes superior knobs, switches, pots, etc., can often



■ FIGURE 3.



■ FIGURE 4.

be found in the surplus market.

## Construction

Figures 3 and 4 show the finished project. The enclosure shown is a nice, inexpensive instrument type box from Jameco. It may appear that a much smaller box could be used, but the reduced front panel size would not provide sufficient space for all the knobs and

switches. The SMD components were loaded using a fine point soldering iron and tweezers. No special tools were needed. I did find it extremely helpful to get someone else to hold the SMD parts in place until I got one or two leads soldered.

Keep in mind that there is no substitute for careful inspection of SMD soldering. (I recommend you read the article on soldering surface-mount parts by R.L. Doerr in the

*Nuts & Volts* January 2009 issue.) There are some good DIY videos on the Internet. Be careful to orient the ICs correctly.

The parts are mounted in varying directions on the PCB to keep the traces short — especially in the high frequency area. I suggest you load the SMD components first to give the best access to the very small pins you will be soldering. You may want to use a larger soldering iron tip on the



thru-hole parts as the power planes are heatsinking.

One of the more difficult parts of any homemade equipment is creating a good looking front panel. I chose a minimalist approach, i.e., just enough lettering to identify the various controls and switches, and no more.

The front panel is drilled before the lettering is applied, eliminating a lot of planning and coordination of the exact location of the switches and potentiometers. That is, the holes for the switches do not have to be placed in precise locations to match the lettering; the lettering is placed after the holes are drilled.

Using self-adhesive paper (Avery labels), I print the lettering with an inkjet printer and then seal the print with a spray-on fixative. The lettering is then cut to size and applied to the front panel. This technique creates a functional and good looking front panel with minimal effort. (Or, you can use services from companies such as **FrontPanelExpress.com.**) Feel free to rearrange the front panel to suit your needs.

Any single pole rotary switch with nine or more positions can be used. A common variety found in the hobby/surplus market is the one pole/12 position type. The specified switch (Mammoth Electronics #820-1P2-12T) has a stop feature that allows rotation to be limited to the nine positions needed for this project. (Mammoth Electronics will give a 15% discount if you mention *Nuts & Volts*.)

If you choose to use a switch without a "position stop," connect the extra positions together with the first or last position so the circuit outputs a signal when one of the extra positions is selected.

Note: When wiring the frequency range switch (SW1), increasing frequency with clockwise rotation requires the switch to be wired in the opposite direction of the schematic numbering: f1 goes to switch position 9; f2 goes to switch position 8; etc.

## PARTS LIST

QTY	DESIGNATOR	DESCRIPTION
7	C1-C3, C5, C7, C9, C10	0.01, radial ceramic, 50V, 10%, XR7
32	C4, C6, C8, C11-C39	0.1, radial ceramic, 50V, 20%, Z5U
4	C40-C43	22 $\mu$ F, 10V
1	C44	22 pF, radial ceramic, 100V, 5%, C0G (NP0)
1	Ctf	82 pF, radial ceramic, 100V, 5%, C0G (NP0)
1	Ctp	47 pF, radial ceramic, 100V, 5%, C0G (NP0)
1	D1	1N4148
1	OSC	10 MHz
1	R1	200, 5%, 1/4 watt
1	R2	220, 5%, 1/4 watt
3	R3, R4, R11	1K, 5%, 1/4 watt
1	R5	100K, 5%, 1/4 watt
1	R6	200, 5%, 1/4 watt
1	R7	220, 5%, 1/4 watt
1	R8	10K, 5%, 1/4 watt
2	R9, R10	51, 5%, 1/4 watt
4	RN1-RN4	10K Eight-pin resistor network-bussed
2	U1, U5	Schmitt trigger inverter - SOT-23
4	U2, U3, U7, U10	Configurable multi-function gate - SOT-23
2	U4, U6	Dual FET bus switch - SOIC
2	U8, U9	Dual J-K flip-flop - SOIC
8	U11-U15, U17-U20	Dual decade counters - DIP
4	U15, U16, U21, U22	Quad bus buffer gate - DIP
1	U23	Hex inverter - DIP
1	U24	Dual peripheral drivers - DIP

### Panel Mount Components

1	LED1	Green
1	LED2	Red
2	POT1, POT2	10K audio
2	SW1, SW2	Rotary switch, SP-12 pos
1	SW3	Toggle switch, SPDT on-none-on
1	SW4	Momentary toggle switch, SPDT on-(on)
3	SW5-SW7	Toggle switch, SPDT on-on
3		BNC or RCA phono jacks
2		Grounding lugs
2		Knob/range
2		Knob/adj
1		Instrument case
1		Power supply, 5V/0.5A regulated

*A more detailed Parts List with both manufacturer and distributor part numbers is available at the article link.*

The potentiometer housings need to be grounded to stabilize stray capacitance in the oscillator adjustment circuits. Start by scraping the paint on the inside of the front panel around the potentiometer's mounting hole. Then, use a grounding lug with a star washer when mounting the pot. Connect the lug to ground using the corresponding hole provided on the PCB (GFp and GPp). If you don't have a grounding lug, you can wrap a piece of bus wire around the bushing and use a regular star washer.

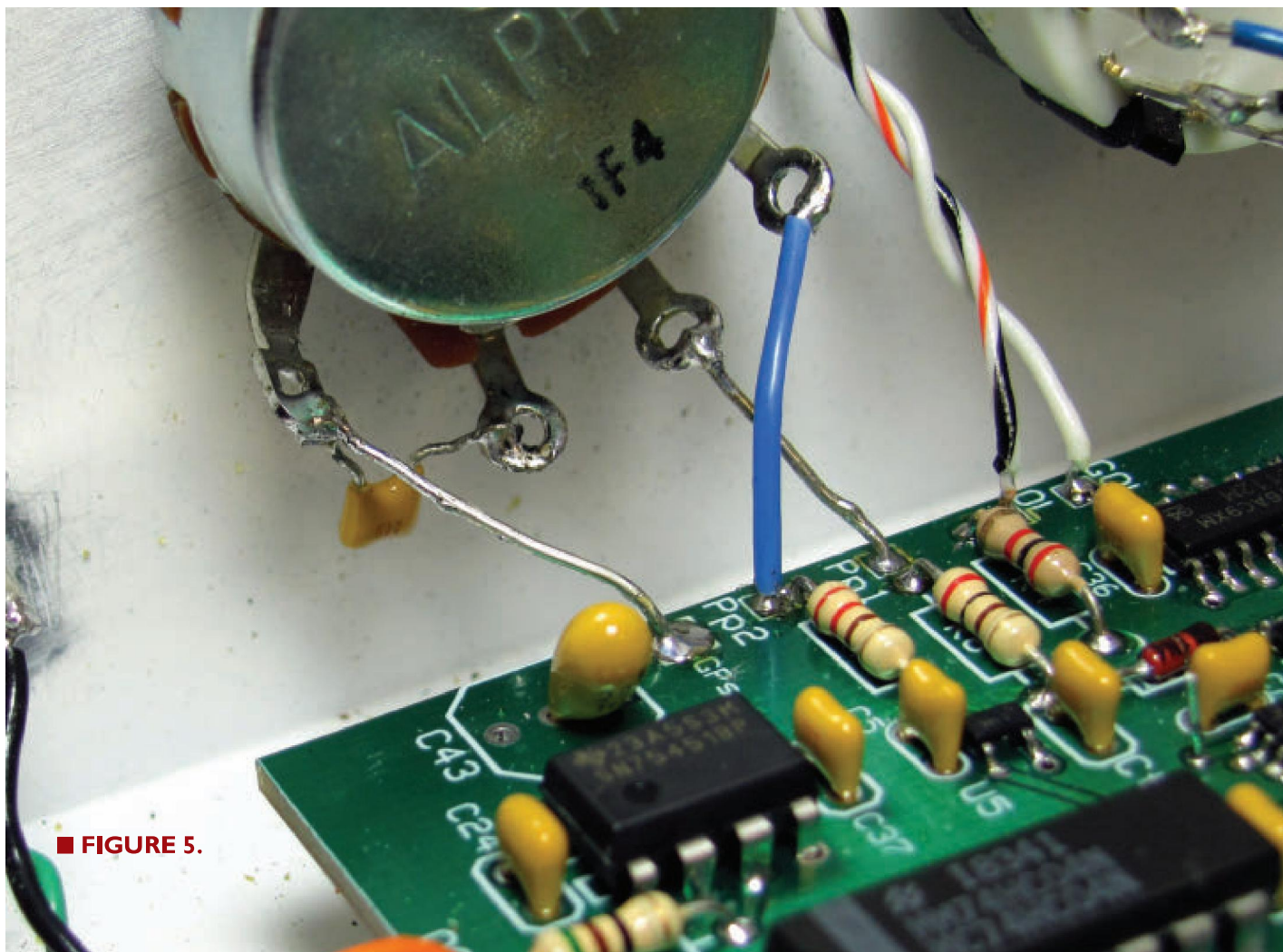
Note: Capacitor C44 is mounted at the pulse width ADJ potentiometer (POT2) between the potentiometer and the ground lug (wire); see

**Figure 5.** A grounding lug is specified in the **Parts List**. Wiring to the switches is not critical. Just hook them up neatly and you will be fine. (Refer back to **Figure 4.**) The LEDs are held in place with glue.

Either RCA phono jacks or BNC connectors can be used for the outputs. The phono jacks are much less expensive, and sufficient for most uses. Wiring to the outputs should be short and neat twisted pairs.

The outer ring of the connectors should also be connected to the case by removing the paint and using a star washer.

When mounting the PCB, use metal stand-offs and star washers so that the ground plane (top side) is



■ FIGURE 5.

connected to the case. The external input was placed on the rear panel, assuming infrequent use.

If you don't implement the complete circuit, be sure to pull up or pull down any unused inputs (e.g., if the crystal oscillator is not loaded, a 10K resistor from the crystal oscillator output on the PCB to either +5V or Gnd will keep U2 pin 1 from floating).

After the PCB is loaded, temporarily wire in the ADJ pots and verify the functionality of the circuit (just in case there is a solder bridge or other problem). Using temporary connections (clip leads/wires), check all switch functions.

## Using the Pulse Generator

The pulse generator is used to

create logic level signals that are needed to check out electronic projects. It can be used during the design, development, or checkout of logic or microprocessor circuits where external inputs need to be simulated.

I have recently used it on projects such as an anemometer, an automobile over-speed alarm, and a stepper motor controller.

The pulse generator typically provides pulses simulating a "logic clock" but can also be used in less obvious ways. For example, a 1 Hz frequency can easily and accurately be obtained by setting the frequency to 1.000 kHz and then changing the "range" switch by three decades to get to an output of 1 Hz.

Another use that may not be obvious is to put the generator in the "single" mode and flip the polarity

switch ( $\pm$ ); you now have a logic level that can be changed without the "contact bouncing" that occurs when connecting and disconnecting a clip lead.

Please try using the open collector output. This approach can save hours of confusion that is caused when inadvertently powering a circuit from the driven output of a signal source, or breaking something by driving current into it unintentionally.

The PCB is available at the *Nuts & Volts* webstore. If you wish to have your own boards made, I have included the Express PCB board files at the article link. There are also additional drawings and information at the article link.

Always check to see if there are any updates at the link before building. **NV**



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microMedic  
2013 National Contest

By Bryan Bergeron

# The microMedic Kit

*This is a review of the microMedic Contest Kit, designed to support the 2013 microMedic National Contest sponsored by the US Army's Telemedicine and Advanced Technology Research Center ([www.tatrc.org](http://www.tatrc.org)) in collaboration with Carnegie Mellon Entertainment Technology Center and Parallax, Inc.*



**Figure 1.** Basic microMedic kit contents (Propeller version).

applications and products for possible use in the healthcare industry, medical simulation training, and the battlefield. As part of the contest, Parallax will distribute 100 free microMedic kits.

To qualify for a free kit, simply submit a preliminary description of your project idea and promise to participate in the contest. Independent judges will identify which proposals to reward with a free kit on a first come, first served basis. See <http://learn.parallax.com/micromedic> for contest rules. If you don't snag one of the 100 free kits or if you want an additional kit, you can purchase one (Arduino or Propeller) from Parallax for \$279.99.

## What's in the Box?

The microMedic kit is available in Propeller or Arduino versions. In addition to either a Propeller Board of Education or Arduino Board of Education Shield (no processor), each kit includes SpO<sub>2</sub> (saturation of peripheral oxygen), color, differential pressure, motion, heart rate, temperature, and Hall effect sensors.

There is also a five-digit seven-segment LED display, LED bar graph, and IR emitter, as well as a nebulizer, blood pressure cuff, and IR remote control. The postage

**T**he microMedic contest — which runs from January 4 to July 31, 2013 — provides \$25,000 in awards for anyone or any team submitting projects that use microcontrollers and sensors to create medical



stamp sized heart rate receiver is so thin that I almost overlooked it.

As shown in **Figure 1**, the basic kit also contains a smattering of miscellaneous components including a handful of capacitors and resistors, an LM358 op-amp, a pair of magnetic reed switches, a pair of rare earth super magnets, signal diodes, four-direction tilt sensor, and a variety of connectors. There is also a modest supply of old fashioned pH paper.

Unless you're in the medical field, you may not have encountered an SpO<sub>2</sub> sensor. The fingertip sensor (see **Figure 2**) is a disposable adhesive unit that contains a pair of LEDs (one IR and one red) and a detector. The ratio of red/IR absorbed as light from the two LEDs travels through the tissues of a fingertip, and then indicates the degree of oxygen saturation; 98% is a typical level in a healthy person. At a full sprint, my SpO<sub>2</sub> drops to about 96% — the same value that an asthmatic might have at rest.

Another atypical component is the nebulizer which is a set of plastic tubes and containers designed to create a mist or aerosol that can be inhaled. Like the blood pressure cuff, the nebulizer is a stand-alone device. You'll have to think of clever ways to add sensors to automatically collect physiological data.

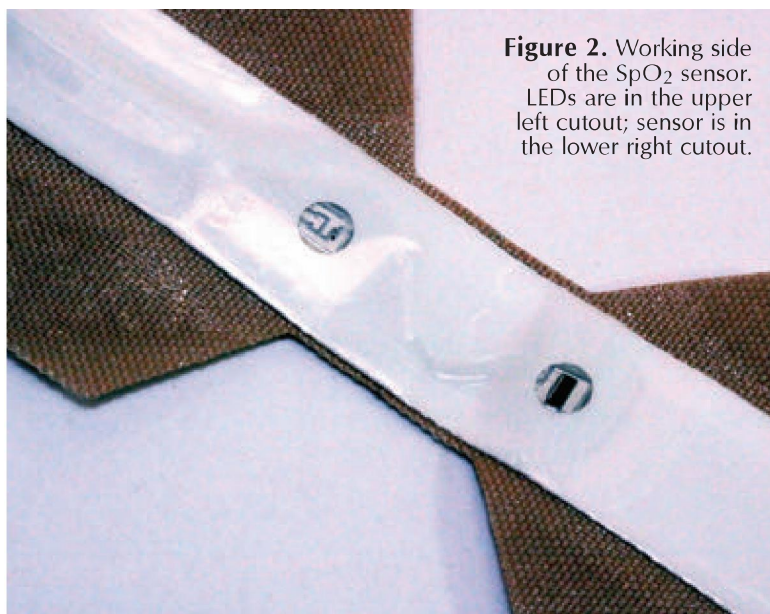
I run with a Polar T34 chest strap heart rate transmitter, so it wasn't much of a surprise. However, what did catch my eye was the matching receiver (see **Figure 3**). My previous experience with a Polar receiver was with a cumbersome 3" x 2" unit. The small, unobtrusive receiver is definitely a plus.

Overall, there's a lot in the microMedic kit to keep anyone busy for weeks, if not months. The non-medical sensors are standard high quality components, and the quality of the medical-specific components seems appropriate for the price of the kit. I would have preferred a non-disposable SpO<sub>2</sub> sensor, but given that my clip-on SpO<sub>2</sub> sensor sells for \$300, I can see the need to go with an affordable option.

Depending on what you decide to build, you'll likely require additional supplies. For example, if you plan to use the blood pressure cuff, then you'll need an inexpensive nursing stethoscope to insure correct placement of the cuff. At a minimum, you'll probably want a project enclosure of some type.

## Let's Build Something

Continuing with the idea of an objective quantitative pH paper reader, let's use the ColorPAL color sensor to quantify the color of a test strip, using the color guide from the bag containing the pH strips as a standard (see **Figure 4**). I don't know about you, but I have

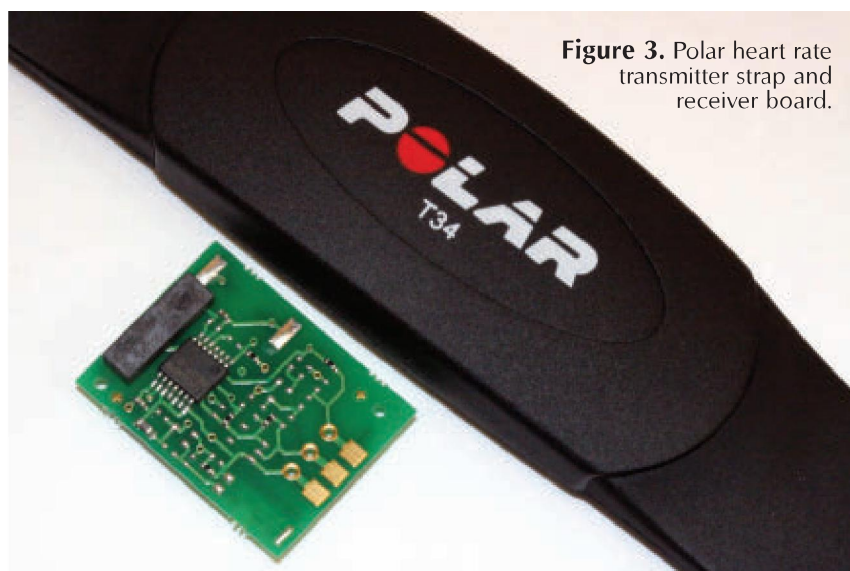


**Figure 2.** Working side of the SpO<sub>2</sub> sensor. LEDs are in the upper left cutout; sensor is in the lower right cutout.

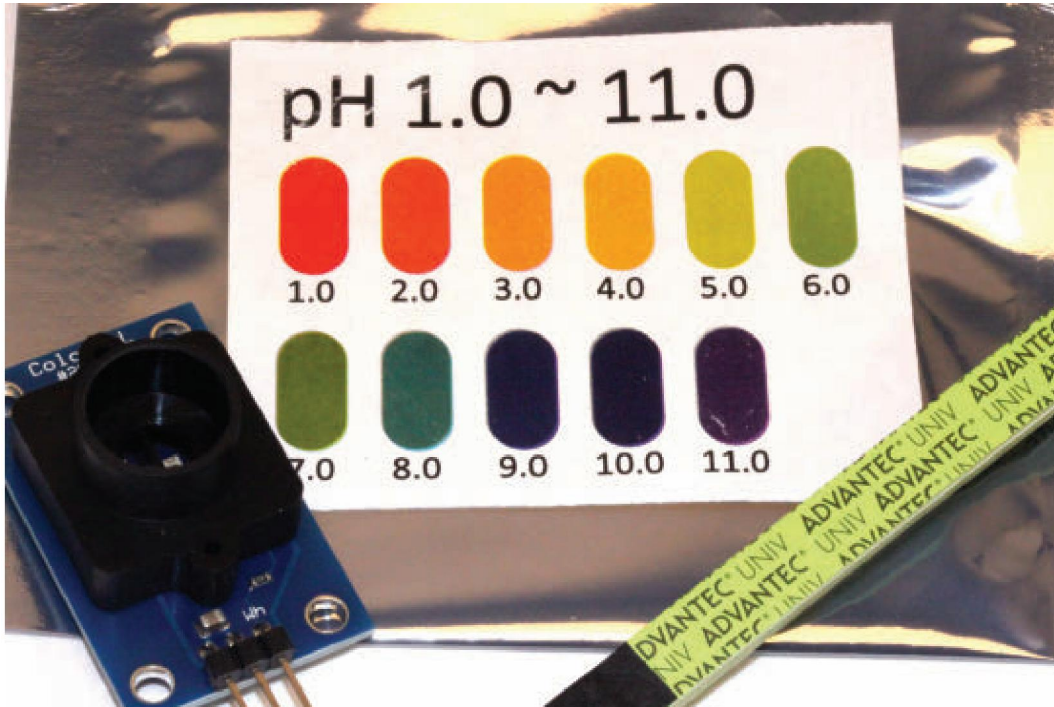
trouble consistently mapping colors to the color guide. For example, I can guesstimate the mid-point between the pH values of 3 and 4, but not between the values of 1 and 2. What, for example, if you have two people reading test results, and one is, say, red-green colorblind? We need a better way.

Recall that pH paper is an indication of the hydrogen ion concentration of a solution. Acids have a low pH, as low as 1 or red. Bases have a high pH, as great as 11 or purple. Neutral pH is 7 or green. Regular table vinegar has a pH of about 2.5 (orange-red).

The normal pH for blood is between 7.35 and 7.45, or slightly alkaline. The pH of tears is limited to a narrow range from about 6.5 to 7.5, or light green to dark green. Urine, on the other hand, is more exciting — at least in terms of reading pH with paper strips. The pH of urine varies from about 4.6 to 8, or orange-green to dark green.



**Figure 3.** Polar heart rate transmitter strap and receiver board.



**Figure 4.** ColorPAL sensor, pH color guide, and booklet of pH paper strips.

You'll notice the fresh strips of pH paper are green — meaning a neutral pH of 7. If you handle the strips directly with your fingers, the paper will discolor to indicate the pH of whatever is on your hands. So, use tweezers to handle the strips, and keep the strips sealed in an airtight plastic bag when not in use.

## The Circuit

The ColorPAL is an easy to use, three-pin device: power, ground, and signal. The hookup is hardly worth a schematic, as there are no pull-up resistors or other external components required. The sensor — based on an Atmel ATtiny13A, 10-bit analog-to-digital converter (ADC) — plugs directly into the Board of Education breadboard, but I prefer to use a servo extension cable, like the one included with the kit.

## The Software

To prototype the project concept, I started with the ColorPAL Sense (Spin) code from the Parallax ColorPAL product page. The sample code returns the raw RGB values of color detected by the sensor. If you want to have a digital readout of pH, then you can set up a table to map, for example, the red-orange printed on the pH guide with a pH value of 1. The LED readout that comes with this kit would make a nice digital pH display. Or, you can map the RGB values at a trigger point — say, the light green associated with a pH of 5 with a buzzer or flashing LED. The resulting ketoacidosis alarm would remind the

dieter that it's time to nibble on a carrot.

New to Propeller or Arduino coding? Not a problem. You'll find sample Arduino and Propeller code for all of the sensors in the kit at [learn.parallax.com](http://learn.parallax.com). There's also a moderated forum at Parallax and an email hotline to military medical experts with TATRC who can discuss project concepts with you.

## Application

Ideally, you'd have several standard pH solutions to calibrate the strip color to actual pH. Alternatively, a calibrated digital pH meter would be great to have as a standard. For our purposes, let's

assume that the printed color guide is accurate.

So, for your first experiment, check the pH of your urine. Then, go load up on water and after about 20 minutes, check the pH again. What's the effect of diluting urine on pH? Now, repeat the test after chugging down a few cups of dark coffee. Any change? How about after a tall glass of cranberry juice? Or, a protein-rich slab of beef or fish? Or, after a five mile run in the sun? Do you see a pattern? Can you see applications?

For example, what about a dehydration alarm based on urine pH since a lower than normal pH is consistent with dehydration. Or, how about an 'over-the-top' ketoacidosis alarm for dieters — or soldiers recovering from surgery?

## Final Thoughts

As you can see, there's a LOT in the kit for a team of students, much less a single experimenter to explore. I've only touched on one of over a dozen sensors in the box of goodies and yet have a working clinical device capable of practical application at home or — as the contest designers intend — in the battlefield.

If you check [learn.parallax.com](http://learn.parallax.com), you can read through a list of project ideas, as well as full project examples with source code. I can't wait to see what sort of innovations the contest will foster. So, what are you waiting for? Get your hands on a kit. **NV**



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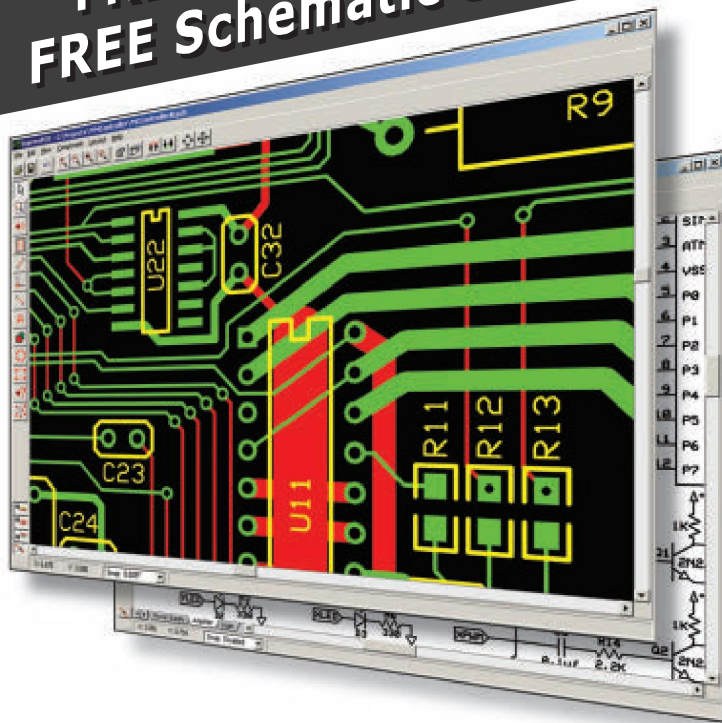
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## YET ANOTHER LED-2X7 PROJECT!

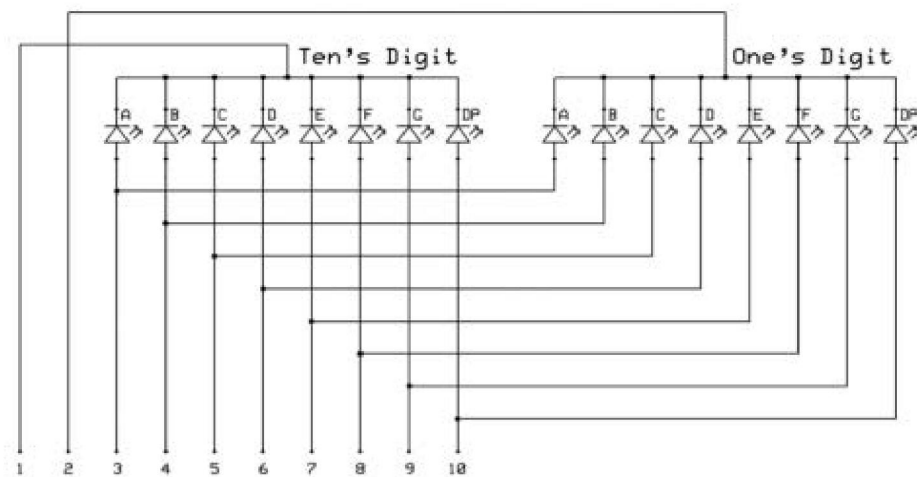
When we completed our experiments with the MCP9700A analog temperature sensor in the previous Primer installment, I was sure that we had also completed our discussion of two-digit, seven-segment LED displays. Well, I was wrong! Shortly after I finished the MCP9700A article, I was searching for something on the Web, and I happened to read some information about the Lumex LDD-N514RI-RA two-digit LED display. The pinout of this display almost perfectly matches that of the 20M2 — so naturally, I couldn't resist experimenting with the new possibilities. As a result, I hope you're ready for yet another LED-2X7 project! Even if you aren't, I would encourage you to continue reading, because this one is going to lead us into a very interesting and powerful feature of the M2-class processors.

Before we begin our exploration of the N514RA display, I want to give you a quick update on my 4.5V (three D cells) battery-powered 20M2 project. When I first powered it up, the battery voltage was 4.8V. It has been happily blinking 24/7 for exactly two months now, and the battery voltage is currently 4.5V. So, things are looking good.

When I finish this installment of the Primer, I plan to add some circuitry to the board in order to increase the current consumption, and then see how the batteries perform. I'll provide a second update in another couple months.

### THE LUMEX LDD-N514RI-RA LED DISPLAY

Let's begin with the pinout of the N514RA which is presented in **Figure 1**. As you can see, the display only has 10 pins, rather than the 18 pins that we've been working with recently. In our previous projects, we simply grounded the display's two common cathode pins, and output the data for both digits simultaneously. However, that approach won't work with the N514RA. If we connect both common cathode pins directly to ground, the same digit would be displayed in both digit positions. In effect, we would have a very simple



■ FIGURE 1. LDD-N514RI-RA LED display pinout.



"count by elevens" project, but I can't think of a useful application, can you?

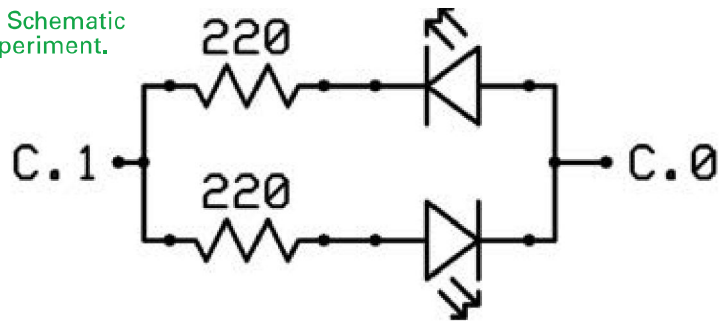
The N514RA is what's called a "multiplexed" display. In order to display a two-digit number, we need to do the following in a loop: Blank the display, output the segment data for the ten's digit, ground the ten's digit cathode (but not the one's digit cathode), blank the display again, output the segment data for the one's digit, and ground the one's digit cathode (but not the ten's digit cathode).

If our loop is fast enough, it will appear to us that both digits are being displayed at the same time, in spite of the fact that they are actually alternating very rapidly. Our visual system just isn't capable of perceiving the extremely rapid alternations as separate events. This phenomenon is known as persistence of vision (POV), and it also explains why we perceive the rapid succession of still images in a video as smooth motion. A multiplexed LED display takes advantage of our visual limitations — in the process, it also decreases the number of data lines that are required to drive a display.

Before we actually design our multiplexed LED display, let's run a very simple experiment that demonstrates how multiplexing works. All we need to do is attach two discrete LEDs to two output pins as shown in the schematic in **Figure 2**. (Note that the polarity of the LEDs is reversed.) I used pins C.0 and C.1 for my experiment, but you can use different pins if you prefer. For clarity, I included the current-limiting resistors in **Figure 2**, but I actually used two resistorized LEDs (as you can see in **Figure 3**, which is a photo of my breadboard setup).

The following code snippet is what I used for the experiment. Just type it into the Programming Editor and download it to your 20M2 breadboard setup. You should see the two LEDs rapidly flickering on

■ **FIGURE 2.** Schematic for POV experiment.



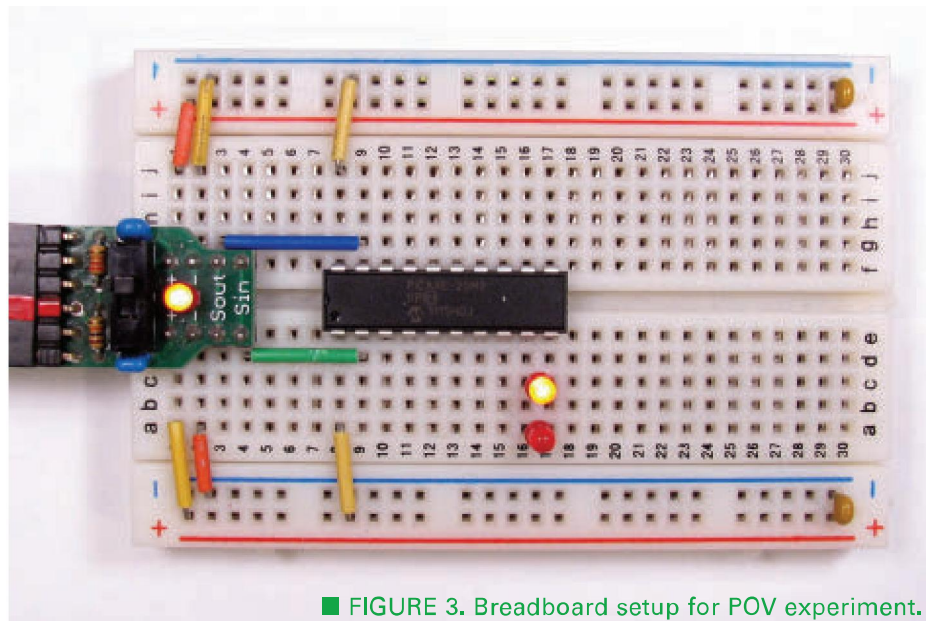
and off in an alternating pattern.

```
' === Constants ===
symbol abit = 18
do
  low C.0
  high C.1
  pause abit
  high C.0
  low C.1
  pause abit
loop
```

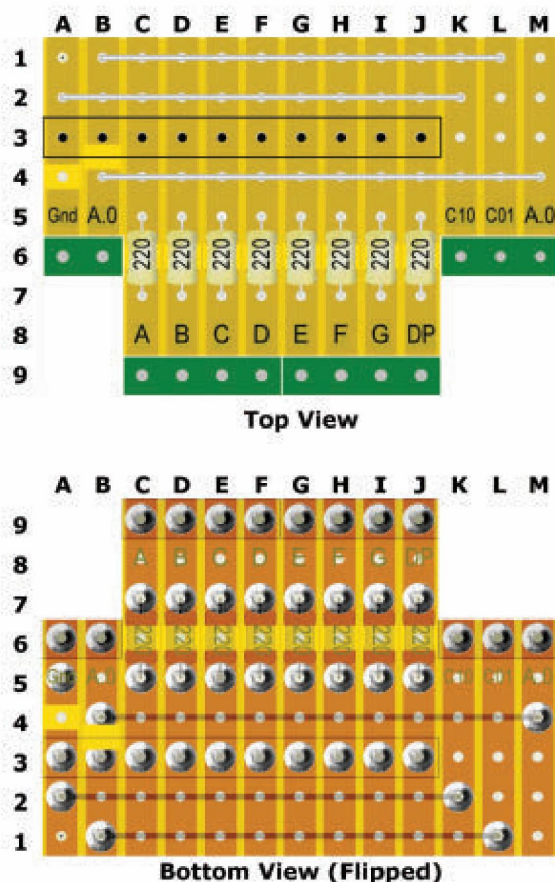
With the *abit* constant set to 18, each LED is lit for about 18 ms, which means that a single iteration of the loop takes about 36 ms. Of course, that's only a rough approximation because the other commands in the loop also take some time to execute. Just out of curiosity, I used my multimeter to measure the frequency of the output wave at pin C.0. It was very close to

25 Hz, so a single iteration of the loop actually took 40 ms (1,000 ms / 25 Hz = 40 ms). At 25 Hz, our visual system is perfectly capable of perceiving the blinking that's actually occurring.

The goal of this little experiment is to determine the frequency at which our POV begins to operate, so I downloaded the code snippet several times, slightly decreasing the value of the *abit* constant each time. When I set *abit* to a value of 10 or less, I could no longer perceive the blinking; both LEDs appeared to be fully on all the time. Therefore, at least for my visual system, a blink-rate of about 50 Hz seems to be the limit; at frequencies higher than 50 Hz, my POV kicks in and prevents me from seeing what's actually happening. You may want to run the experiment yourself to determine the limit for your visual system



■ **FIGURE 3.** Breadboard setup for POV experiment.



■ FIGURE 4. Stripboard layout for N514RA experiments.

## INTERFACING THE LDD-N514RI-RA DISPLAY

If you refer back to the pinout in **Figure 1**, you will see that the 10 pins are drawn in a single row which is typical for LED display pinouts. However, the neat pin arrangement in the pinout diagram is rarely reflected in physical reality; most LED displays have two rows of pins, and the segment order is rarely sequential. The N514RA is an exception; the pinout diagram exactly reflects the physical arrangement of the pins. The physical segment ordering exactly matches the pinout diagram. The N514RA's 10 pins are arranged in a single row along the bottom edge of the display. In

addition, the pins are all bent at an angle which means that the N514RA can be directly inserted into a

breadboard (or a single header on a stripboard — hint, hint), and the eight data pins perfectly line up with the eight port B pins on the 20M2 processor.

Of course, we can't simply insert the N514RA in line with the port B side of the 20M2 because we need to include current-limiting resistors between the port B pins and the display's data pins. Also, the display's two common cathode pins will require additional circuitry before they can be connected to the 20M2 pins. However, a simple stripboard circuit can solve both these problems, allowing us to insert the N514RA on the port B side of the 20M2 so that we can experiment with it.

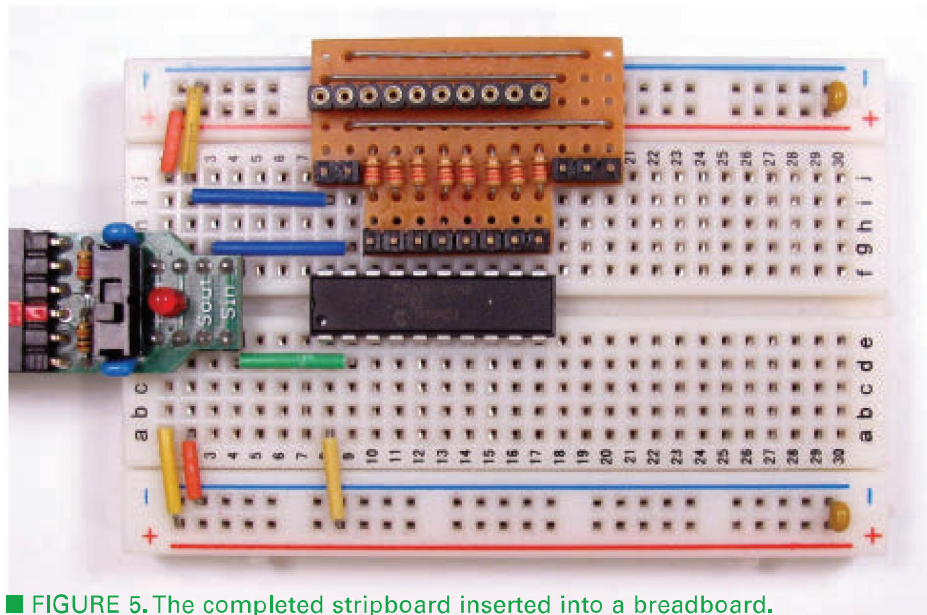
The stripboard layout is presented in **Figure 4**; a larger version is available for downloading at the article link. The stripboard's wiring is fairly simple, so I haven't included a schematic; just refer to the layout in **Figure 4** for the following discussion.

The 10-pin female header near the top edge of the stripboard is where the N514RA will be inserted. The reverse-mounted male headers on the lower edge of the board are inserted next to the port B side of the 20M2, with the ground pin in line with the 20M2's ground pin. (See the photo in **Figure 5**.)

As you can see, we are still able to access the 20M2's ground pin, as well as its serial out pin which you may remember can also be accessed as the "pseudo" A.0 pin. (If not, see the February 2012 Primer installment.) Also, the N514RA's eight segment pins line up perfectly with the port B pins which will simplify the software conversion of a digit to the corresponding LED segment pattern.

The two cutout areas on the bottom corners of the stripboard allow room for the insertion of jumpers or components that we'll be using to interface the display. We won't be using the ground pin at all,

because we'll use that information when we implement our multiplexed LED display.



■ FIGURE 5. The completed stripboard inserted into a breadboard.



as you can see by the cut trace immediately above the pin on the stripboard layout. The only reason I included the ground pin was to avoid using a single-pin male header for the A.0 pin. The N514RA's two common cathodes (ten's digit and one's digit) are brought out to the right side of the stripboard (along with a duplication of the A.0 pin) so that we can have one area in which we can add the necessary interfacing components on the breadboard.

By now, we're familiar with the need to convert each digit to its corresponding segment pattern before we can display the digit on the LEDs. In our previous projects, this process was somewhat complicated by the fact that we needed two different segment patterns for any specific digit because the segment connections differed for the ten's digit and the one's digit. Fortunately, the N514RA uses the same connections for its two digits which simplify things considerably.

**Figure 6** presents a chart of the necessary digit to segment conversion values. In the chart, I have reversed the order of the eight data bits so that the data pattern matches the standard order for binary numbers. For each digit, if a segment needs to be lit the corresponding value for that segment is included in the chart. (Blank cells indicate segments that should not be lit for the specified digit.)

As an example, let's see how I arrived at 91 as the value needed to be output on the port B pins in order to display the digit 2. First, refer to the standard LED segment-labeling pattern presented in **Figure 7**, and you'll see that we need to light the G, E, D, B, and A segments. Next, look at the digital value associated with each segment that we need to light. For example, the G segment is connected to pin B.6 which has a digital value of 64. So,

DP	G	F	E	D	C	B	A	Segment
B.7	B.6	B.5	B.4	B.3	B.2	B.1	B.0	Pin
128	64	32	16	8	4	2	1	Value

Digit								Total
0		32	16	8	4	2	1	63
1					4	2		6
2	64		16	8		2	1	91
3	64			8	4	2	1	79
4	64	32			4	2		102
5	64	32		8	4		1	109
6	64	32	16	8	4		1	125
7					4	2	1	7
8	64	32	16	8	4	2	1	127
9	64	32		8	4	2	1	111

■ **FIGURE 6.** Digit to segment conversion chart.

that value has been entered in the appropriate cell for the 2 digit. When all the necessary values have been entered for a digit, their sum is entered in the Total column. Also, note that the decimal point to the right of each of the display's digits has a value of 128. If you want to show a decimal point, just add 128 to the total segment value for the digit you are displaying.

The fact that the N514RA only needs one value to display a specified digit in either digit position makes this a perfect place to use the PICAXE BASIC lookup command. We've used this command before but it's been a while, so let's review its syntax:

```
lookup offset, (data0, data1,
data2, ... dataN), variable.
```

The offset parameter specifies which data value to assign to the variable parameter. The assignment is "zero-based:" If *offset* = 0, then the *data0* value is assigned to *variable*; if *offset* = 1, then the *data1* value is assigned to *variable*, etc. (If the value of the offset parameter exceeds the number of data values in the lookup table, the variable parameter is not updated. Therefore, assuming we have previously declared the *myDigit* variable, in order to display the

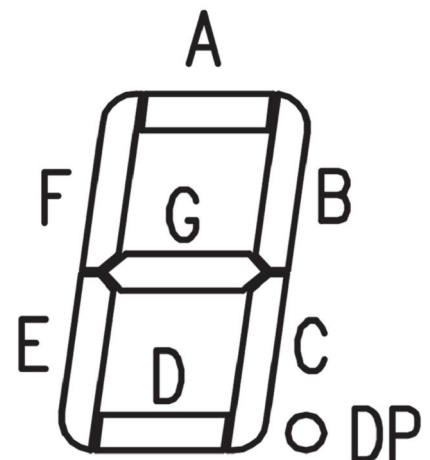
correct segment value for any given digit we need to write:

```
lookup myDigit,
(63,6,91,79,102,
109,125,7,127,111), pinsB
```

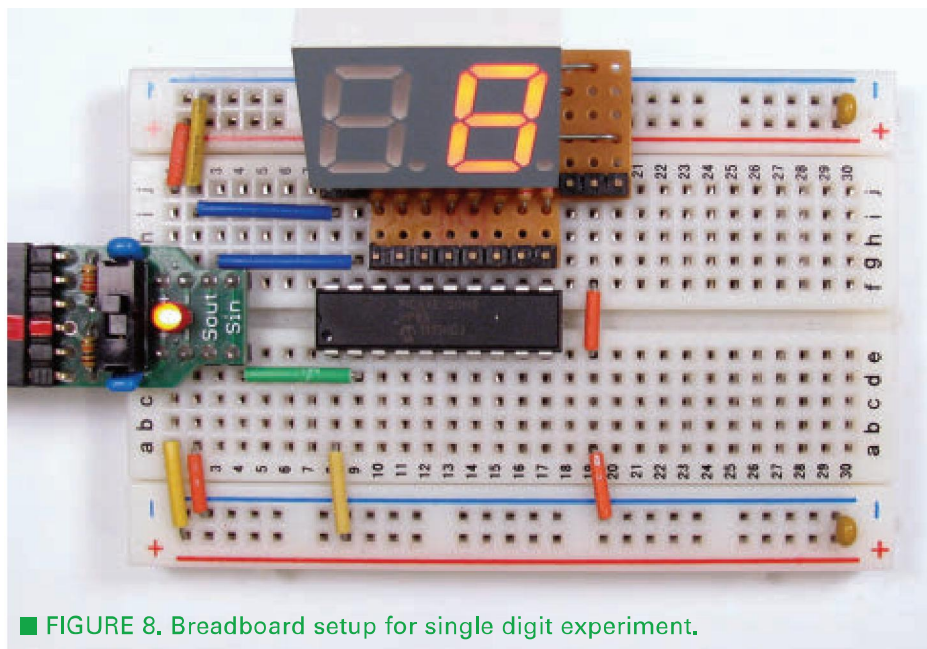
As long as *myDigit* is between 0 and 9, the correct segment pattern will be displayed on the LEDs; it's as simple as that!

## EXPERIMENTING WITH THE N514RA LED DISPLAY

For our first experiment with the completed stripboard, we'll test the



■ **FIGURE 7.** Standard labels for a seven-segment LED display.



■ FIGURE 8. Breadboard setup for single digit experiment.

board by displaying a repetitive count from 0 to 9 on the one's digit of the N514RA. In **Figure 8** (which is a photo of the breadboard circuit), you can see how I connected the 20M2 ground pin to avoid placing a jumper under the N514RA. Also, only the common cathode for the one's digit is connected to ground, so that's the only digit that will light. The software is again simple enough to just type into the Programming Editor. Here's the code snippet:

```
Symbol myNum = b0
do
  for myNum = 0 to 9
    lookup myNum, (63,6,91,
      79,102,109,125,7,
      127,111),pinsB
    pause 500
  next myNum
loop
```

Not a very impressive program, but it does show you whether your board is working correctly. I also ran an even simpler program that just displayed "8." on the N514RA one's digit (note the "."), so that I could measure the maximum current consumption when all eight segments are lit. The total current

consumption was about 66 mA or just over 8 mA per output pin, which is well within the 20M2's specifications.

Of course, our ultimate goal is to multiplex the two-digit display. In order to do so, we can't just connect the two common cathode pins to two of the 20M2 port C output pins. When either of the port C pins is in a low state, it could be sinking as much as 66 mA which is way beyond the maximum pin capability of 25 mA. It could damage or destroy the output pin. The solution — which we used way back in the December 2009 column — is to use bipolar transistors as switches to handle the higher current requirements.

In that installment, we used four KSP2222A NPN transistors to multiplex a four-digit LED display; presently, we could certainly use two NPN transistors to multiplex the N514RA, but this time I was determined to not use any of the port C pins to drive the display. In other words, I wanted to accomplish our goal by using only the "pseudo" A.0 output pin.

Fortunately, NPN and PNP transistors exhibit a complementary

switching action that will do exactly what we need. **Figure 9** is a schematic of an NPN switch and a PNP switch that are both connected to the 20M2 A.0 pin. Below the schematic is a chart that summarizes the complementary switching action of the two transistors. As you can see, when the A.0 output is high the PNP transistor turns off the one's digit segments, and the NPN transistor turns on the ten's digit segments. When the A.0 pin is low, the reverse is true: The PNP transistor turns on the one's digit segments, and the NPN transistor turns off the ten's digit segments. In other words, toggling the A.0 pin toggles the two display digits which is exactly what we want to do.

## MULTIPLEXING THE N514RA LED DISPLAY

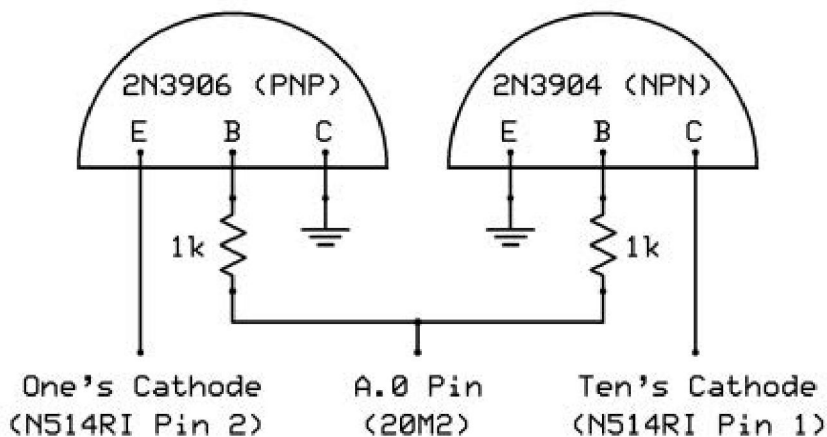
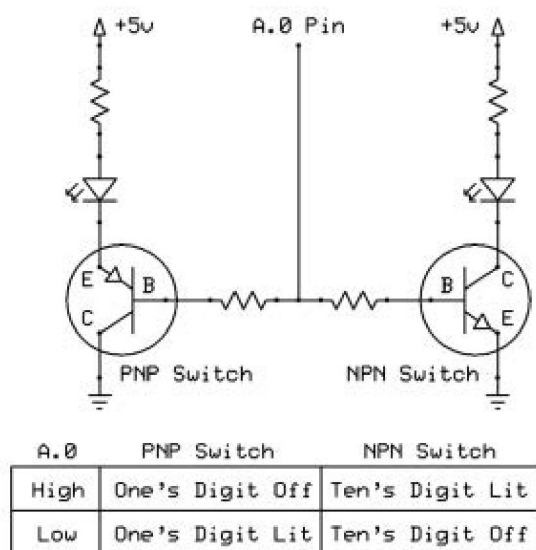
At this point, we're ready to set up the breadboard circuit for our multiplexed LED display. When I implemented my breadboard circuit, I used a 2N3904 NPN transistor and a 2N3906 PNP transistor (which are both available on my website, along with the LDD-N514RI-RA display).

Both these transistors are rated for a maximum continuous current of 200 mA which is more than adequate for this project. Most commonly available bipolar transistors should also work, as long as they can handle the required current flow.

**Figure 10** presents another version of the same schematic that we just saw in **Figure 9**. This time, however, the circuit is drawn in a way that more clearly reflects the breadboard setup that we'll be using. **Figure 11** is a photo of my breadboard setup for the multiplexed display.

When you have completed your breadboard circuit, we're ready to discuss the software for our multiplexing project. There are three important points that we need to keep in mind:





■ FIGURE 10. PNP and NPN switching circuits (Version 2).

■ FIGURE 9. PNP and NPN switching circuits (Version 1).

• **Make It Fast** — In our earlier experiment with the two discrete LEDs, we discovered that we needed to switch the LEDs at a rate greater than 50 Hz in order to avoid seeing any flickering, so our main multiplexing loop must be able to execute at least 50 times per second. Another way to say the same thing is that the loop can't take more than 20 ms per iteration.

• **Keep It Balanced** — The portion of the code that lights the ten's digit should execute in the same amount of time as the portion of the code that lights the one's digit. If the timings aren't equal, one displayed digit will appear brighter than the other.

• **Avoid Ghosting** — We need to make sure that we never change the data that's being output on port B while something is being displayed on the LEDs. If we were to do that, some of the display segments that should be off would appear to be faintly lit — a phenomenon known as ghosting.

Before we're finished this month, we'll experiment with deliberately producing ghosting in order to clarify what this means.

Our multiplexing program

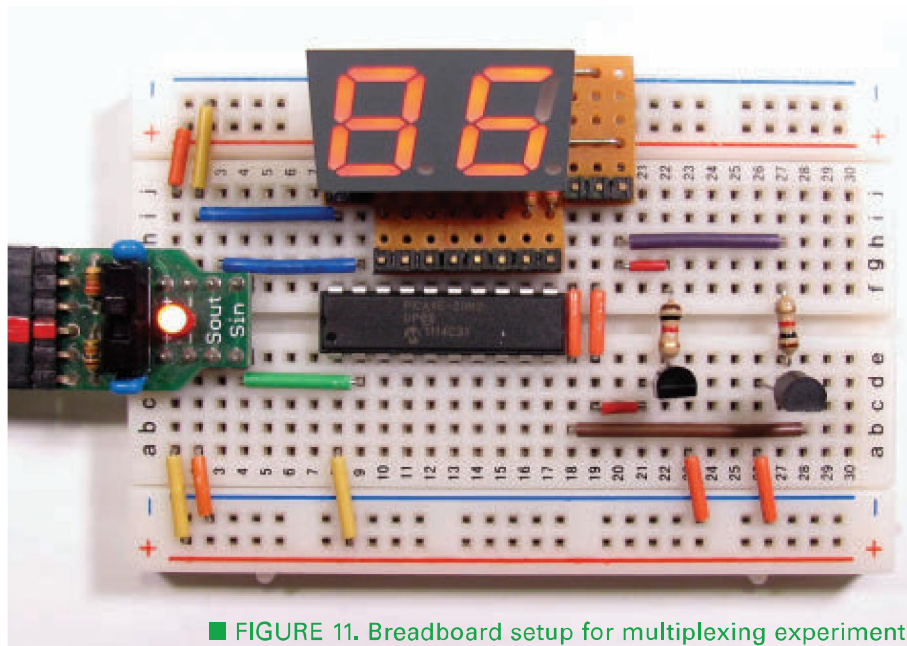
(*LEDmultiCount99.bas*) is available for download at the article link. We still need to discuss how the program implements the three points listed above, but I'm sure you will want to run the program first. When you download *LEDmultiCount99.bas* to your breadboard setup, the display should repetitively count up from 00 to 99 at a rate of one count per second. If not, you will need to check the wiring on your breadboard.

When you're sure your system is working correctly, we can move on

to discussing the details of the program.

As we've done in the past, the number of each of the following comments refers to the corresponding number in brackets at the right-hand edge of the program listing.

- 1) I think we've discussed the time variable in a previous installment, but in case I'm mistaken, let me explain. Time is a built-in word variable that's available in all



■ FIGURE 11. Breadboard setup for multiplexing experiment.

M2-class processors. We don't need to declare time in our program; in fact, trying to do so will produce an error. When a program first starts running, time is automatically initialized to 0, and it automatically increments once per second. In the present program, the *if/then* statement simply restricts the value of time so that it's always between 0 and 99.

- 2) Our two transistor switches always toggle between one display digit and the other. Therefore, the A.0 pin doesn't provide a way of turning off both display digits at the same time. In effect, setting *pinsB* equal to 0 accomplishes this for us, because a value of 0 results in none of the segments being lit. Once we have "turned off" the display, we can move on to the next instruction without producing any ghosting.
- 3) Placing A.0 in a low state activates the one's digit on the display, but *pinsB* is still 0,

so nothing shows up yet. Before reading further, you may want to experiment with ghosting at this point. If so, edit the program by removing or "commenting out" the *pinsB = 0* statement, and download the program again. In the one's digit of the display, you will see what ghosting looks like.

- 4) In this statement, we're simply converting the digit that we want to display to its corresponding segment pattern, and placing the resulting value in the *pinsB* variable which displays the digit correctly on the one's digit LEDs.
- 5) A pause statement is included at this point to balance the timing. At the bottom of the *do/loop*, the second lookup instruction displays a digit in the ten's digit position on the display, and then the program loops back to the top and tests the time variable again. Both of those processes (looping back and testing time) take a certain amount

of time to execute. As a result, if we omitted the *pause* statement, the ten's digit would be displayed for a longer amount of time than the one's digit. Try it. Remove or "comment out" the *pause 4* statement, and download the program again. What happens? By the way, I arrived at the value of 4 by trial and error (until the brightness of the two display digits looked the same to me). You may want to adjust my value up or down a little. Finally, in the program listing, the comments for the ten's digit portion of the loop (6, 7, and 8) have the same explanation as 2, 3, and 4 above.

At this point, you may have concluded that the timing requirements of a multiplexed display are somewhat demanding. If so, you would be absolutely correct! When I first began experimenting with the N514RA, I thought that the speed requirement would be the biggest problem.

However, that doesn't seem to be the case. I measured the frequency of the main *do/loop* in the *LEDmultiCount99.bas* program at 120 Hz, so even if we were to add a fair number of programming tasks to the *do/loop*, it would still probably run fast enough to avoid flickering.

However, the "balancing" requirements are another story. Any time we add additional code in the part of the loop that updates the one's digit of the display, we also need to add code in the part of the loop that updates the ten's digit of the display.

If we didn't do that, one digit of the display would appear to be brighter than the other. Of course, we could adjust the *pause* statement to compensate for that, but it would require a constant



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"juggling" of code as a project is being developed.

Back in the original Primer article on multiplexed LED displays (December 2009), the stringent timing requirements are what led us to the MAX7219 display driver in the first place. (As you know, the MAX7219 completely relieves the main processor of all the tasks related to multiplexing an LED display.)

However, the M2-class processors (which were not yet available at that time) now include a new feature that may well make it possible to do the job without the help of a separate (and expensive) driver chip.

That feature is called Parallel Task Processing, and next time we'll explore how it can simplify the task of multiplexing the N514RA display.

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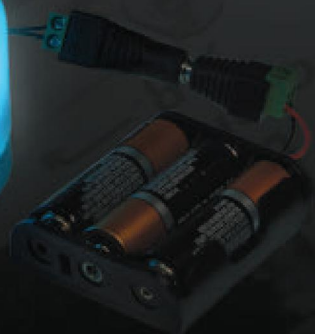
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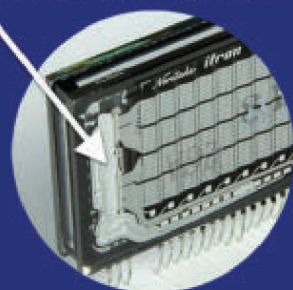
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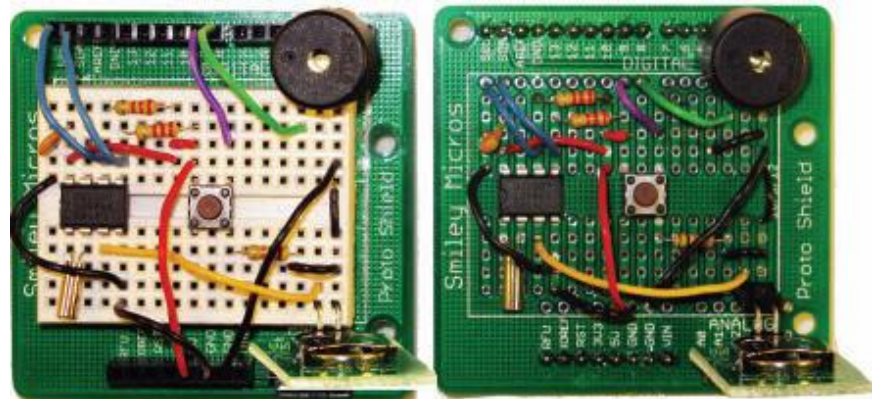
## #55 WORKSHOP

C PROGRAMMING - HARDWARE - PROJECTS

## Part 2 ARDUINO PROTO SHIELD ALARM CLOCK

**L**ast month, we finally finished our Fritzing workshops with a brief introduction to the new parts editor. We then learned how to move our proto shield alarm clock from the breadboard to the PCB (printed circuit board; **Figure 1**). We were also introduced to the Arduino alarm clock software (**Figure 2**).

The associated parts kit (**Figure 3**; available from the *Nuts & Volts* Webstore) allows you to follow the materials presented in Workshops 52 through 55. With this kit, you can create both the breadboard and the PCB versions of the Arduino proto shield based alarm clock. This month, we are going to dig into the software for both the Arduino and PC, and we'll take a general look at how dates and times are handled on microcontrollers.



■ FIGURE 1. Proto shield alarm clock on breadboard and PCB.



■ FIGURE 2. Arduino alarm clock application.

### INTRODUCING DATE AND TIME ON A PC

First, let's take a look at how dates and times are handled on a PC. We will discuss the way Unix and C handle them by using some examples written in C, and then we'll run them on the PC using the free Pelles C compiler (discussed back in Smiley's Workshop 23 in the June 2010 issue). You can get Pelles C for free at [www.smorgasbordet.com/pellesc](http://www.smorgasbordet.com/pellesc), but please donate a few dollars to help support this excellent learning tool.



### How Time Data is Stored

Back in Workshop 48 (July 2012) when we studied data structures and enums, we chose to use time data for our examples. While helping us to understand how to use data structures, the examples weren't how the data is actually structured in the C standard library, so let's look at how the big boys do it.

First, we will look at the central timekeeping data structure *tm* which is located in *time.h*:

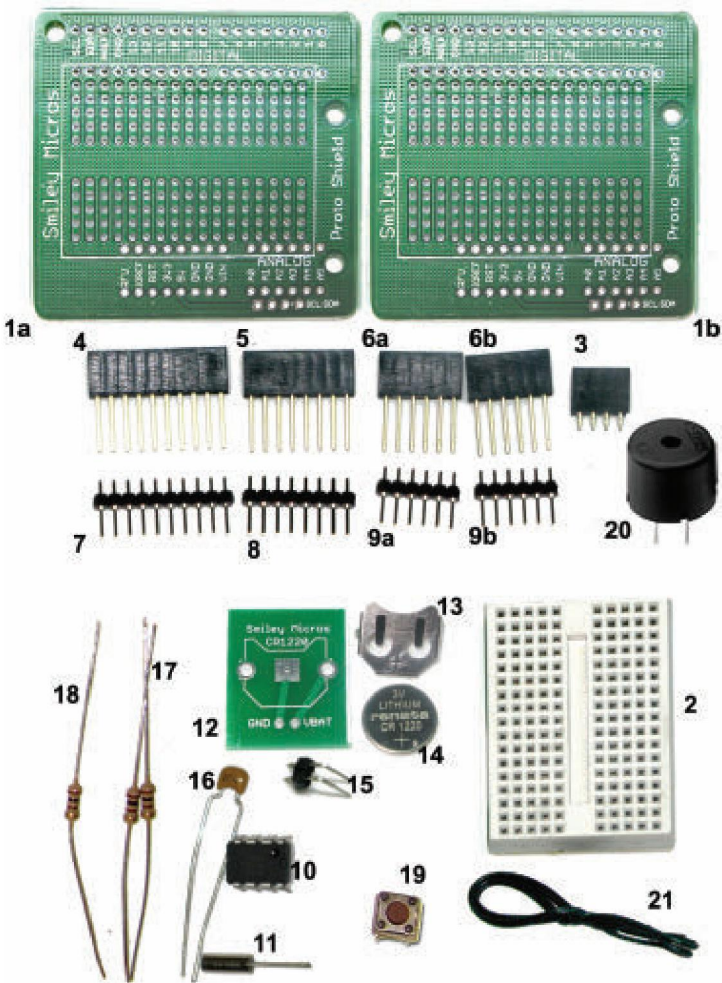
```
struct tm {
    int tm_sec; /* seconds after the minute [0-61]
    int tm_min; /* minutes after the hour [0-59]
    int tm_hour; /* hours since midnight [0-23] */
    int tm_mday; /* day of the month [1-31] */
    int tm_mon; /* months since January [0-11] */
    int tm_year; /* years since 1900 */
    int tm_wday; /* days since Sunday [0-6] */
    int tm_yday; /* days since January 1 [0-365] */
    int tm_isdst; /* Daylight Savings Time flag */
};
```

That just about covers everything we'll need to express a date or time.

Now that we have a structure to hang things on, we need a compact way to store a date and time. Our structure has nine ints — most of which are far larger than necessary for storing a particular value. For instance, *month* only has values of 0 to 11 which could easily be stored in four bits. Since an *int* is usually 16 bits on a microcontroller, that's a lot of wasted space.

We use *ints* because they are the unit of data exchange in most microcontrollers, so it is easier for the device to deal with *ints* rather than other data types that aren't physically present on the machine.

Of course, early microcontrollers were four-bit machines so an *int* was perfect. Devices in use today are usually 16 bits, but can easily be 32 or even 64 bits.



■ FIGURE 3. Arduino proto shield alarm clock kit.

Item	Description
1a, 1b	Two proto shield PCBs
2	One mini breadboard
3	Four-pin female header
4	10-pin shield header
5	Eight-pin shield header
6a, 6b	Six-pin shield header
7	10-pin male header
8	Eight-pin male header
9a, 9b	Six-pin male header
10	One DS1307 RTC IC
11	One 32,768 kHz watch crystal
12	One breadboard battery PCB
13	One battery holder 12 mm coin
14	One battery CR1220
15	One two-pin 90 degree male header
16	One capacitor 0.1 μF
17	Two resistors 2.2K ohm
18	One 10K ohm pull-up resistor
19	One pushbutton
20	One piezo buzzer
21	Two feet of uncut jumper wire

Table 1. Bill of Materials.

To keep C simpler, we just use the *int* data type and let the compiler deal with the actual size. This still doesn't deal with all the wasted space for storing the data, so we'll define a new data type — *datetime* — that on Unix type systems is 32 bits. We use this to store the number of seconds since January 1, 1970 Greenwich Mean Time. Say what?

Well, that particular time was chosen as the beginning of the epoch for time keeping in Unix systems, so it is now available in most PC type systems. We declare this as:

```
typedef long time_t;
/* time in sec since 1 Jan 1970 0000 GMT */
```

Just FYI, this will store the number of seconds to get us to Jan 19, 2038 where it will roll back to 1901 and likely cause headaches much like the Y2K bug was supposed to (but didn't). So, since the Mayan *datetime* data type was wrong and the world didn't end December 21, 2012, keep an eye out for 2038.

We also have a variable for storing the time since a software process started as a function of processor ticks, *clock\_t*:

```
typedef long clock_t;
/* time in ticks since process started */
```

This variable depends entirely on the processor and how it counts ticks. Since AVR's tick at millions of times per second, this is more useful for determining how long a particular section of code takes to complete than it is for keeping track of time on a human scale.

Finally, for more human friendly units, we define *CLOCKS\_PER\_SEC* which is a device dependent number that tells how many ticks in *clock\_t* are equal to one second.

## Time Manipulation Functions

**time()** — Returns the time since the beginning of a system epoch. In the case of Unix, that is the number of seconds since Jan. 1, 1970.

**clock()** — Returns a processor tick count.

**difftime()** — Calculates the difference between times.

## Format Conversion Functions

Uses the *tm* calendar type.

**asctime()** — Converts a given calendar time to a textual representation.

**ctime()** — Converts a given time since the epoch start to a local calendar time and then to a textual representation.

**strftime()** — Converts date and time data from a given calendar time to a formatted null terminated string.

Uses the *time\_t* — time since epoch type.

**gmtime()** — Converts a given time since the epoch start to a calendar time expressed as Coordinated Universal Time (UTC).

**localtime()** — Converts a given time since the epoch start to a local calendar time.

**mktime()** — Converts calendar time to a time since the epoch start.

## Using *time.c* on a PC

Let's see how this all plays out on a PC by getting some time. First, let's see how many system ticks there are in a second on my PC. We run the following *DateTimeTest1.c* in Pelles C:

```
#include <stdio.h>
#include <time.h>

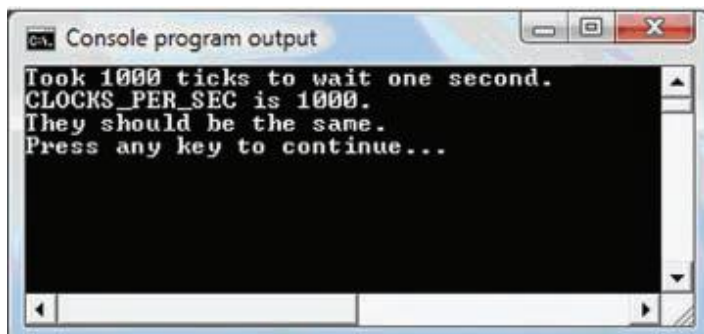
int main(int argc, char *argv[])
{
    // define two variables of type clock_t
    clock_t ticks1, ticks2;

    ticks1=clock(); // get the number of ticks
                    // since the process started
    ticks2=ticks1; // make a copy of it

    // wait for 1 second to pass while getting
    // the ticks
    while((ticks2/CLOCKS_PER_SEC-
    ticks1/CLOCKS_PER_SEC)<1)
        ticks2=clock();

    printf("Took %ld ticks to wait one
    second.\n",ticks2-ticks1);
    printf("CLOCKS_PER_SEC is
    %ld.\n",CLOCKS_PER_SEC);
    printf("They should be the same.\n");
    return 0;
}
```

Turns out that there are 1,000 system ticks per second on my PC. This should allow us to time intervals down to a single millisecond.



■ FIGURE 4. Clocks per second.



Next, let's write *DateTimeTest2* and see how many seconds it has been since January 1, 1970:

```
int main()
{
    time_t myTime; // define a time_t variable

    time(&myTime); // use as a pointer to get the
                  // time in seconds

    printf("It has been %ld seconds since Jan. 1 1970\n",myTime);

    return 0;
}
```



■ FIGURE 5. Seconds since epoch began.

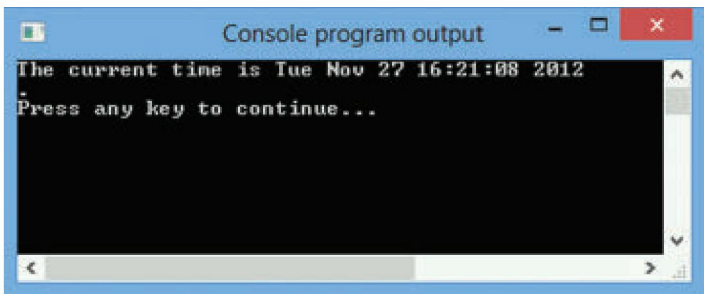
Good grief, has it really been that long? It's 1,335,989,666 seconds already and it seems like only yesterday (which is me being sarcastic about how useful that number is to tell when now is). So, what is the date and time that this number represents? Well, let's use the *asctime()* function in *DateTime3* to get the date and time in a format that makes sense:

```
int main()
{
    time_t myTime; // define a time_t variable

    time(&myTime); // use as a pointer to get
                  // the time in seconds

    printf("The current time is\n%s.\n",asctime(localtime(&myTime)));

    return 0;
}
```



■ FIGURE 6. *DateTimeTest3*.

We used the *localtime* function to convert the time since the beginning of the previously mentioned epoch into a calendar time, and then used the *asctime()* function to convert that into a string that we can then show on our console window using the *printf* function.

Next, let's write *DateTimeTest4* to get the epoch time, and then convert that into the *tm* data structure so that we can manipulate each aspect of the date and time as separate variables:

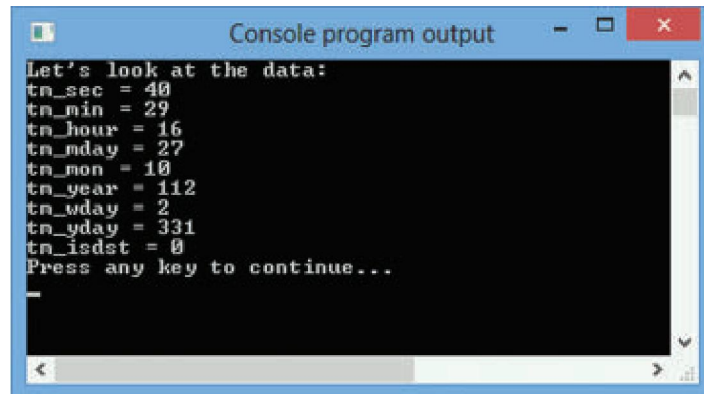
```
int main()
{
    time_t myTime; // define a time_t variable

    time(&myTime); // use as a pointer to get
                  // the time in seconds

    // load a pointer to a tm struct with the
    // local time
    struct tm* time_parts = localtime(&myTime);

    printf("Let's look at the data:\n");
    printf("tm_sec = %d\n",time_parts->tm_sec);
    printf("tm_min = %d\n",time_parts->tm_min);
    printf("tm_hour = %d\n",time_parts->tm_hour);
    printf("tm_mday = %d\n",time_parts->tm_mday);
    printf("tm_mon = %d\n",time_parts->tm_mon);
    printf("tm_year = %d\n",time_parts->tm_year);
    printf("tm_wday = %d\n",time_parts->tm_wday);
    printf("tm_yday = %d\n",time_parts->tm_yday);
    printf("tm_isdst = %d\n",time_parts->tm_isdst);

    return(0);
}
```



■ FIGURE 7. Show the *tm* structure.

Wait a second. The year is 112? Well, I neglected to mention that the year is calculated by adding the value in *tm\_year* to the constant *TM\_YEAR\_BASE* that just happens to be 1900. So,  $1900 + 112 = 2012$  and we are right on time. You might notice that the month is 10, but in *DateTime3* we saw that it is November. What gives?

Well, months are 0 based, so January is 0 and December is 11. We could take care of this in the software, but it is good to reinforce what we are doing by seeing the raw output.

You now have a good introduction to how C handles dates and times on a PC, so let's see how we do this on the Arduino.

## INTRODUCING DATE AND TIME ON A MICROCONTROLLER

As you may remember, the Arduino uses some standard C and C++ stuff based on the resources in WinAVR. Unfortunately, one of those resources (avrlibc) does not implement the standard C library *time.c* and *time.h* files. This is because the functions in those files require some sort of built-in timekeeping facility that usually comes with an operating system, but are not available in a raw AVR that is small and has no OS.

In order to use these functions, we have to build our own custom timekeeping system. Since there are so many ways to do this, the folks who did avrlibc thought it best to leave it to the programmer of a particular system.

We've seen how this is done with regular C and an operating system by using Pelles C. Now, we will look at a way of using some similar concepts on the Arduino using an external IC — the DS1307 real time clock — as our arbiter of dates and times.

### Our Windows Alarm Clock Software

We probably could have written something to communicate with our Arduino on the PC using Pelles C, but I find Visual C# much quicker and with more attractive results. So, I wrote the PC side application for the Arduino alarm clock in Visual Studio C# Express 2012 for Windows Desktop.

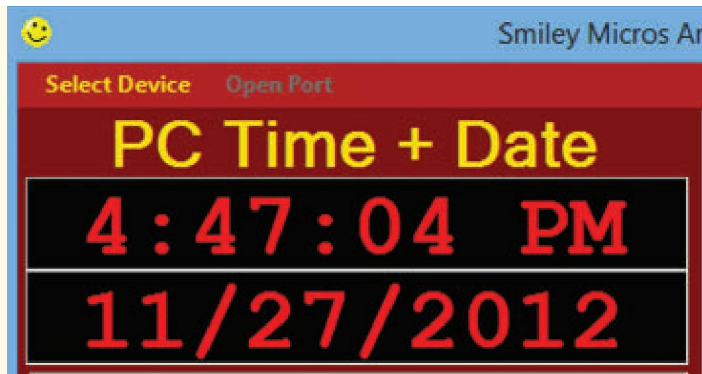
I also wrote several articles about using a virtual serial port with C# that were published in the January, February, and March 2010 issues. These might provide a good introduction if you aren't already familiar with creating PC applications with C#.

### Showing the Date and Time on a PC

Microsoft uses a *DateTime* value type that can represent Gregorian calendar dates and times from 00:00:00 (midnight) January 1, 0001 to 11:59:59 P.M., December 31, 9999. This is divided into 100 ns ticks, allowing us to represent any 100 ns interval in the above range as a single number — a very big number — but that's what PCs are good at. So, let it worry about storing and converting the number of ticks from the beginning of the Common Era to this very moment.

It is very easy to use *DateTime* in C# once you know how, but it can be very hard to figure out how to use it at first. That may sound like some nonsense, but look at the following example. We create the date and time displayed on the left of **Figure 8** using the following two lines of code:

```
labelTime.Text = DateTime.Now.ToLongTimeString();
labelDate.Text = DateTime.Now.ToShortDateString();
```



■ FIGURE 8. PC date and time.

Two lines of code. How simple is that? Darn simple, actually, but it is a real bear to figure out what you really need to use from the many *DateTime* functions available. For all I know, it may not be the best way. However, it does work, so I'll live with it.

You have a choice of becoming an expert in C# or relying on your Google-Fu and finding working examples. I prefer the latter technique.

### Sending the Date and Time to the Arduino

So, how easy is it to send the date and time from the PC to the Arduino? Just look at the following code:

```
TimeSpan _UnixTimeSpan = (DateTime.Now - new
DateTime(1970, 1, 1, 0, 0, 0));
richTextBoxReceive.Text += "unixtime = " +
    _UnixTimeSpan.TotalSeconds.ToString()
    + "\n";
serialPort1.WriteLine("P" + _UnixTimeSpan
    .TotalSeconds.ToString() + '!');
```

You just instantiate a *TimeSpan* object to this particular 100 ns interval, then subtract the number of 100 ns ticks since the beginning of Unix time, and send that number to the Arduino. Yup, it's another totally easy thing to do. (We won't mention the hours of Google-Fu'ing around the Internet it took to find those three lines of code, however.) Luckily, you can get the C# code for the PC side of the Arduino alarm clock at the link for this article, so you can reuse these concepts for your own PC side application. Just be aware that the code I'm providing (while working just fine) looks a bit like road-kill under a magnifying glass, so I recommend squinting when you use it.



## ALARM TYPES

While we can have up to 65,535 different alarm types, in our example we only have two: 'One shot' and 'Daily.' You might want others such as 'Weekly' that would activate once per week, or perhaps 'On event' that creates an alarm to activate at a specific duration after an input (maybe you have a rain detector and you set an alarm to go off in two hours to check a rain gauge, then you get a tweet with the value). There are endless possibilities, and as I've said before, you have the source code to add whatever you like.

### How to Set an Alarm

In order to set an alarm, first open the dropdown box

and click on the desired alarm as shown in **Figure 9**.

Next, we open the alarm type dropdown box and select either One shot or Daily as shown in **Figure 10**.

Now, we click on the calendar selector as shown in **Figure 11**. By the way, this really shows the power of using something like C# since all one has to do is drag and drop this component, click, click, and you've got a powerful graphical element at your disposal.

Finally, we select the time as shown in **Figure 12** and then click the 'Set Alarm' button. The alarm is now set.

Well, that was certainly easy, and, of course, you've got all the source code at your disposal.



■ FIGURE 9. Select the alarm.



■ FIGURE 10. Select the alarm type.



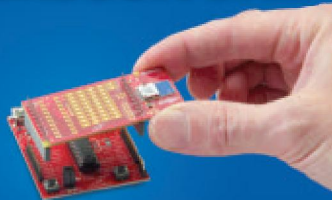
■ FIGURE 11.  
Select the date.



■ FIGURE 12. Select the time.



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## HOW RTCLIB TELLS TIME

*RTCLib* was written for the Arduino in C++ by Jean-Claude Wippler of [jeelabs.org](http://jeelabs.org) — be sure to check out his website. He chose to create his own version of some of the data structures used in the C standard library *time.c*, and since we are using his library we'll discuss his version of the *DateTime* object.

His original code was oriented to getting the *DateTime* values. I modified it to allow setting them, and I changed the name to *AlarmClockRTCLib* to hopefully prevent confusion. My modifications are included in the software download package at the article link.

The purpose of this library is to allow us to store a Unix date and time as a 32-bit unsigned integer, and then set or get the year, month, day, hour, minute, and second from that value.

### Using *RTCLib* with the Arduino

First, we must include the header:

```
#include "Wire.h"
#include "AlarmClockRTCLibSW.h"
```

We include *Wire.h* because the *RTCLib* uses the I<sup>2</sup>C bus that has functions defined in *Wire.h*. We then use the functions from the *RTCLib* library in our *initializeDS1307RTC()* function from the Arduino project *Alarm\_Clock\Alarm\_Clock\_Time* module. In this function, we run:

```
RTC.begin();
// initialize the DS1307
```

This function uses the I<sup>2</sup>C bus to set up the DS1307 for our use. You can look at the code in the *RTCLib.cpp* to see how this is done. This also gives a good introduction to using the I<sup>2</sup>C bus with the Arduino.

How do we monitor the clock against the alarm? I initially expected it ended up running *Timer1* and ticks to set a flag (*n* to 1) and in the *loop()*

function, I check to see if this flag is set. If so, I call a function to handle the situation. Running this only once per second allows the Arduino to do other tasks in the background, such as communicating with the PC and running the piezo alarm.

Each time the Arduino *loop()* function sees that flag set, it checks the time against the alarms and sets them accordingly:

```
// timer sets check_alarm
// once per second
if(check_alarm){
  if(alarm1_set){
    go_alarm1();
  }
  else if(alarm2_set){
    go_alarm2();
  }
  else if(alarm3_set){
    go_alarm3();
  }
  else if(alarm4_set){
    go_alarm4();
  }
  else if(alarm5_set){
    go_alarm5();
  }
  check_alarm = 0;
}
```

Each *go\_alarm#()* function may be written however you wish, depending on what you want to do with a particular alarm.

To keep track of alarms, we use integer variables for each alarm: *alarm#\_set*, *alarm#\_tripped*, and *alarm\_type*. While the first two are used as Boolean values with only 0 and 1, the third would allow us to define 65,535 possible types of alarms — far more than we'll need. We set all these variables to 0 when we run *initializeDS1307RTC()*.

Well, look at the time! I guess we will have to continue this next month. Since this is a work in progress, the actual code [that you can get from the article link] may have a few things different that what we've discussed here, but nothing major. Besides, all differences will be documented in the code. **NV**



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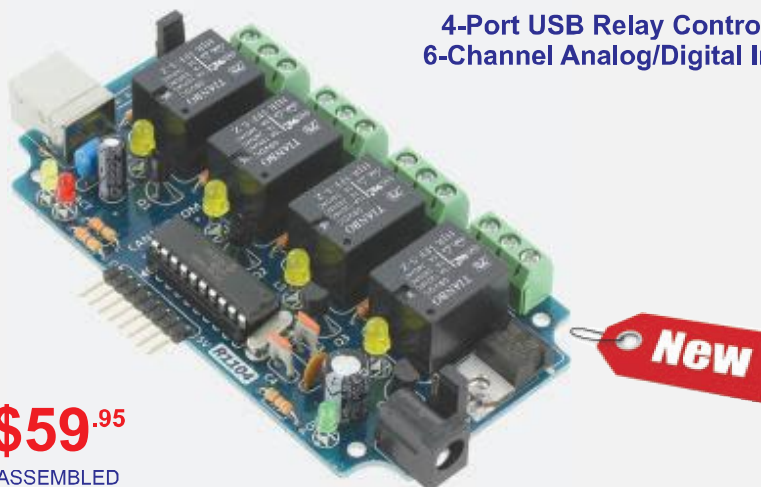


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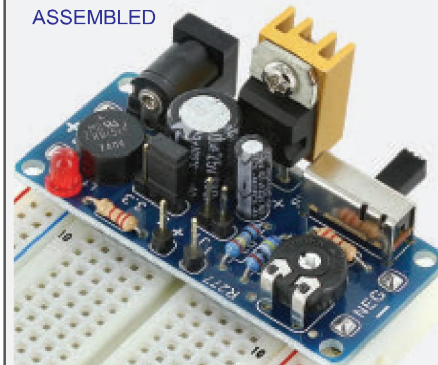
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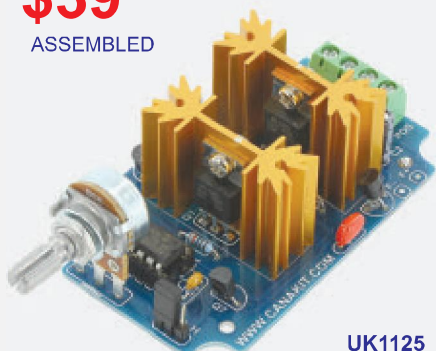


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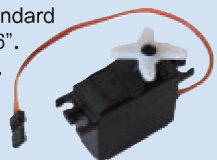
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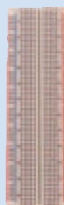
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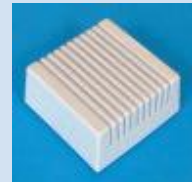


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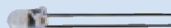


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THE LATEST IN NETWORKING AND WIRELESS TECHNOLOGIES

## This Wireless Technology Will Dominate The Cellular Radio Space. *Have You Got It Yet?*

**If you have a cell phone — especially a smartphone — you probably have heard the initials LTE. It means Long Term Evolution, but that's not saying much, and it certainly doesn't give you a clue about what it really means or stands for. LTE is a cell phone radio technology that is gradually replacing current 3G technologies like CDMA2000 and WCDMA/HSPA. One of these days, you will own an LTE cell phone if you don't already.**

LTE is also a standard developed by the Third Generation Partnership Project (3GPP). This international group developed the 3G standard designated UMTS WCDMA, and have now moved on to the fourth generation (4G). The LTE standard was finalized in 2010, and the 3GPP has moved on to complete a major upgrade to LTE called LTE Advanced. The 3GPP considers LTE to be a 3G technology (or 3.9G as some call it). However, most cellular carriers call LTE 4G. The real 4G is LTE-A.

### WHY LTE?

The motivation behind the development of LTE is the explosive increase in data services on cell phones, including text messaging, email, Internet access, shopping, banking, gaming, music, and video downloads. This data tsunami has stressed most cellular operator's infrastructures to the point they cannot fully provide the high speeds expected by subscribers. Adopting LTE will increase data rates and simultaneously boost subscriber capacity.

LTE provides high speed wireless mainly to cell phones, but it is also being incorporated into tablets. LTE dongles or data cards for plugging

into USB ports make LTE available on laptops, as well. Another growing application is wireless broadband. This is the use of LTE in fixed wireless services to provide high speed Internet access to homes and businesses in rural areas and small towns where the usual DSL or cable TV services are not available. LTE is also being looked at as a potential replacement for some types of public service two-way radios.

Besides providing very high mobile data rates, LTE is being adopted because of its high radio link reliability. It uses multi-carrier modulation techniques in wide bandwidths to make the overall signal immune to multipath propagation, fading, and other effects that occur at UHF and microwave frequencies. This ensures a solid connection under noisy and high rate mobile conditions.

LTE is so good that practically all cellular carriers are adopting it as a replacement for all previous forms of 2G or 3G technologies. This replacement is happening gradually not only in the US, but worldwide. Adoption of LTE is at different stages in different parts of the world, but is probably farther along in the US than in most other countries.



## THE RADIO TECHNOLOGY

LTE is a mobile broadband wireless system that features high data rates, low latency, improved subscriber capacity, and coverage. It is based on the modulation method known as orthogonal frequency division multiplexing (OFDM). This is a multi-carrier system that divides the useable spectrum into many narrow band subchannels or subcarriers. Several hundred or several thousand subcarriers are used. The high speed serial data representing the data to be transmitted is subdivided into many slower data streams; these are then used to modulate each subcarrier in parallel. This method spreads the signal over a wide bandwidth, making it less affected by fading and multipath signals created by reflections. The overall effect is a more solid wireless link.

OFDM is the modulation method of choice for most new wireless (and wired) systems. It is used in TV data transmission worldwide (not in the US), HD radio, wireless LANs using Wi-Fi, and wireless broadband systems. Even power line communications (PLC) that send high speed data riding on the AC power lines use OFDM. Despite its popularity, it is an amazingly complex technology. The only way to achieve

OFDM practically is to create it using mathematical techniques implemented with digital signal processing (DSP). Separate DSP microprocessors or FPGAs are commonly used to create OFDM.

LTE is designed to accommodate multiple users in the same spectrum. The technique is known as OFDM Access or just OFDMA. This method allots groups of subcarriers for each user in the LTE bandwidth. The bandwidth of an LTE signal is divided up into segments called resource blocks that are 180 kHz wide. Each resource block is made up of 12 OFDM subcarriers, each with a bandwidth of 15 kHz. The number of subcarriers assigned to each user is based on multiple factors like speed, user contract specifics, and the amount of traffic being handled.

So far, we have been talking about OFDM for the downlink — the wireless connection from the base station to the handset. The uplink technology is different. It uses single carrier frequency division multiple access (SC-FDMA). This is a technology similar to OFDM and is often called spread OFDM, where the OFDM signal is only a single

carrier that is further spread by coding over the available bandwidth to improve link reliability from the handset. It uses less power so as to help preserve battery power.

LTE is so good that practically all cellular carriers are adopting it as a replacement for all previous forms of 2G or 3G technologies.

The LTE standard supports bandwidths of 1.4, 3, 5, 10, 15, and 20 MHz. This flexibility allows each wireless carrier to match the desired data rate and capacity to their available spectrum holdings. The modulation can be QPSK, 16QAM, or 64QAM. The maximum typical data rates are 100 Mb/s downlink and 50 Mb/s uplink. The latency is less than 10 ms.

A key feature of LTE is the use of multiple input multiple output (MIMO) antenna technology. MIMO uses multiple transmitters, receivers, and antennas to increase data speeds and provide mitigation of fading and multipath conditions that let the carrier implement a more reliable connection.

What MIMO does is divide up the fast serial data into multiple streams, and transmits these different parallel signals simultaneously over the same frequency bandwidth. With special coding and taking advantage of the spatial differences in each received signal, the parallel data streams can be recovered and the original fast serial data can be reconstructed. MIMO allows the overall data rate to be multiplied by the number of streams used. Some of the MIMO formats supported are 1x2, 2x1, 2x2, and 4x4, where the first number means the amount of transmit antennas and the second number is the amount of receive antennas. Using a 20 MHz

## What is 3GPP?

The 3rd Generation Partnership Project (3GPP) unites [six] telecommunications standards development organizations (ARIB, ATIS, CCSA, ETSI, TTA, TTC), and provides their members with a stable environment to produce the *Reports and Specifications* that define 3GPP technologies.

The four Technical Specification Groups (TSG) in 3GPP are Radio Access Networks (RAN), Service & Systems Aspects (SA), Core Network & Terminals (CT), and GSM EDGE Radio Access Networks (GERAN).

Each of the four TSGs has a set of Working Groups, which meet regularly four to six times a year. Each TSG has its own quarterly plenary meeting where the work from its WGs is presented for information, discussion, and approval. Each TSG has a particular area of responsibility for the *Reports and Specifications* within its own Terms of Reference.

The 3GPP technologies from these groups are constantly evolving through generations of commercial cellular/mobile systems. Since the completion of the first LTE and the Evolved Packet Core specifications, 3GPP has become the focal point for mobile systems beyond 3G.

For more information about the 3GPP, visit [www.3GPP.org](http://www.3GPP.org)



bandwidth, a downlink speed of up to 300 Mb/s can be achieved with 4x4 MIMO, and up to 150 Mb/s is possible with 2x2 MIMO.

To implement full duplexing — meaning simultaneous transmit and receive — LTE uses frequency division duplexing (FDD). This is the process of using two separate chunks of spectrum: one for the downlink and the other for the uplink. The spectrum segments have to be separated from one another; enough so that with filtering, the transmitter won't interfere with the companion receiver. This is the system currently used by all cellular systems in the US and in most other countries. It works great but requires lots of spectrum.

Another LTE duplexing technique is time division duplexing (TDD). This system uses different time segments in which to transmit and receive. The timing is so fast a user cannot tell that alternating talk-listen time segments are occurring. Therefore, this method requires precise timing. The big benefit is that only one segment of spectrum is needed. This arrangement is a more economical

use the higher cellular bands between 1,800 and 2,600 MHz, depending on the country of origin and the carrier's spectrum assignments. LTE also uses the newer 700 MHz spectrum available to some carriers. There are a few dozen specific LTE bands, and each carrier is assigned certain ones. This means

■ **FIGURE 1.** These new smartphones use LTE. The iPhone 5 is the first Apple phone to use LTE. The Nokia Lumia 920 also incorporates LTE and uses Microsoft's new Windows Mobile 8 operating system.



## VOICE ON LTE

LTE is a packet-based system that uses the Internet Protocol. For that reason, it is a data only technology; it does not carry voice traffic. That means LTE phones also incorporate older GSM or CDMA technology for



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## LTE STATUS

Cell phone companies are slowly rolling out LTE systems. At present in the US, Verizon is in the lead with AT&T not far behind. Sprint, MetroPCS, and US Cellular have also deployed a few LTE systems. T-Mobile will be following up this year and next. Right now, there are several hundred LTE base stations deployed, mostly in the larger cities and metropolitan areas. If you live in one of the major cities, you can get LTE service right now. However, it will be a while before it trickles down to the smaller markets. This will occur as the carriers get the needed financing and spectrum. In the meantime, the 2G and 3G services will be maintained.

Part of the slow growth of LTE has been the lack of a large number of LTE phones. The usual chicken and egg problem applies here. Some smartphones are available now and more are on the way. Two of the available LTE phones are the Apple iPhone 5 and the Nokia Lumia 920 shown in **Figure 1**.

Your next smartphone will probably have LTE, and I believe you'll be delighted with the performance. Data speeds are remarkable. You won't get the maximum LTE rates discussed above, but you will probably average

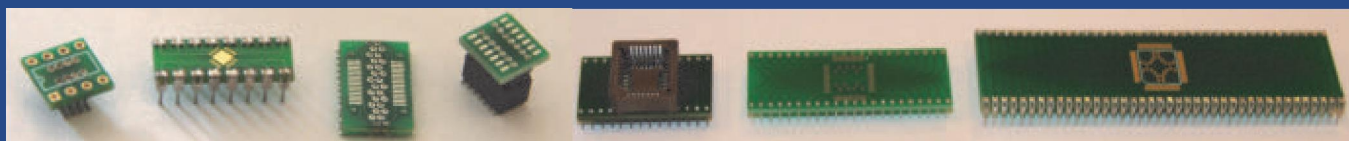
download speeds in the 10 to 15 Mb/s range — far faster than most 3G systems. Some even claim that they get better download speeds with their LTE phones than they do from their DSL or cable Internet service.

## BEYOND LTE

Revised standards from 3GPP have recently become available. Known as LTE Advanced, this upgraded standard uses new methods to get even higher data rates. One of these new methods is called carrier aggregation. This technique combines two or more 20 MHz LTE bandwidths up to a maximum of 100 MHz into a single band, where larger OFDM signals can be accommodated. Wider bandwidth — of course — means higher speeds.

LTE-A also adds increased MIMO variations up to 8x8. Using these techniques, it is possible to achieve peak data rates in the 300 Mb/s to 1 Gb/s range. LTE-A is not deployed yet, but manufacturers are working on it. Look for some LTE-A in 2014 and beyond. **NV**

small scale, so it's not yet widely used. It is estimated that it may come into use in 2014 and later. In the meantime, LTE phones will continue to carry 2G voice radios for phone calls.



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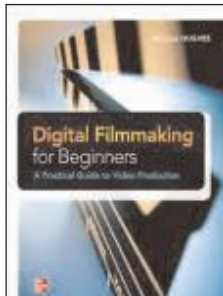
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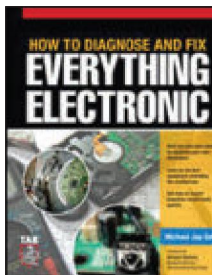
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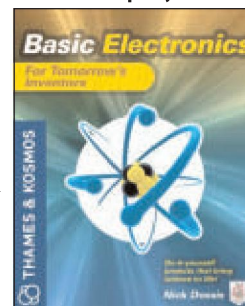
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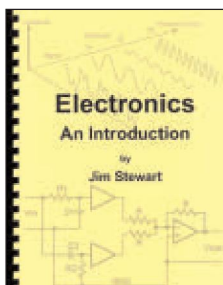


### Electronics An Introduction

by Jim Stewart

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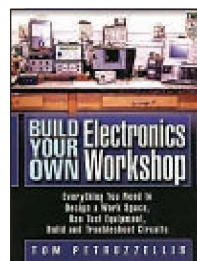
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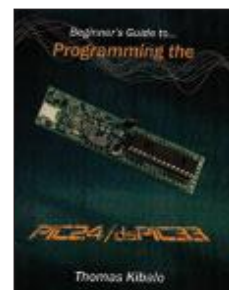
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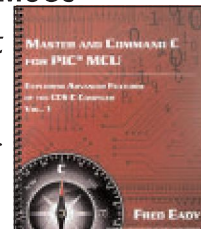
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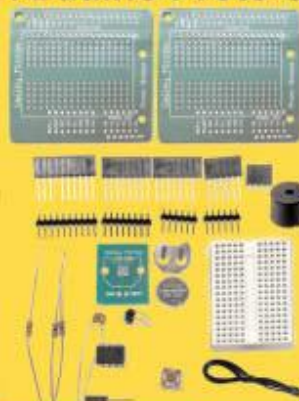


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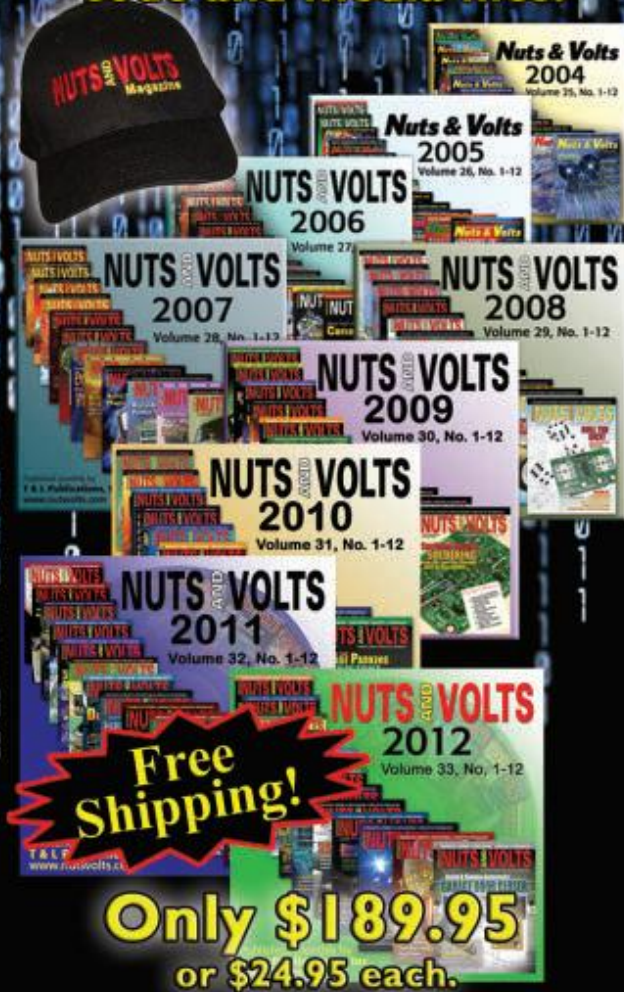


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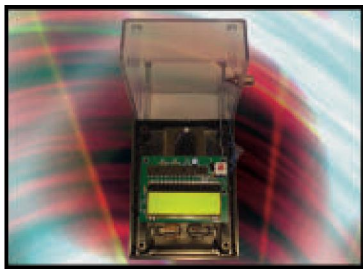
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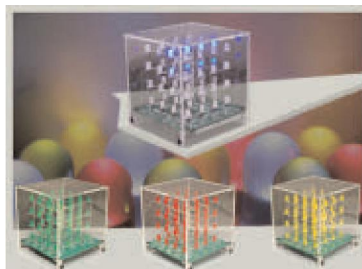
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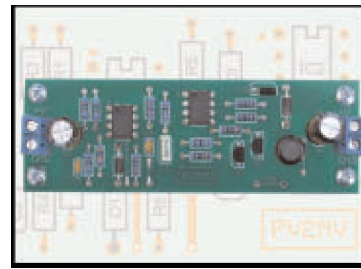
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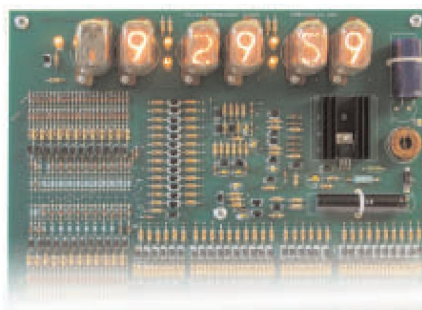
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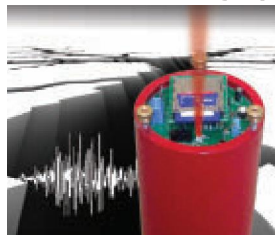
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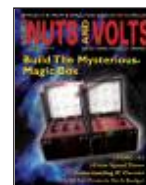


As seen in the May 2012 issue. Now you can record your own shaking, rattling, and rolling.

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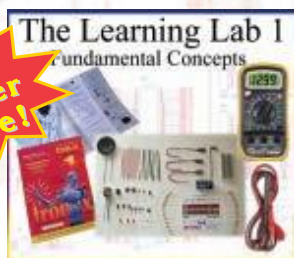


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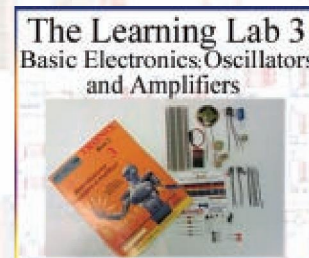
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state gear, well designed and made tube equipment can keep this to inaudible levels.

Audiophiles (people who desire near perfect sound reproduction) sometimes also use tube preamps and power amps, and they would not tolerate these noises at any volume level. What sounds really absurd is that guitar players would generate several to many watts of audio power, only to dissipate it all as heat and only use a small sample of the signal voltage to drive another amplifier input. More needs to be done to understand the distortion of overdriven tube power amps and duplicate this on a preamp or line level circuit.

The output transformers used in tube guitar amps are smaller than those in high fidelity amplifiers using the same output tube types and having the same power capabilities.

As a result, their cores saturate more at lower frequencies, making the lower notes even more fuzzed than the higher ones. Do the current distortion processors simulate this too?

**Michael Kiley  
Crestwood, IL**

**Response:** I agree that not all tube equipment is inherently noisy. I have a tube-based 'audiophile' headphone amp that is simply amazing.

However, when it comes to guitar amps, someone interested in clean, pure tones isn't going to invest in a tube amp. Solid-state amps are a better choice. It's for this reason you won't find many tube-based amps for acoustic guitars. Electric guitar players after 'vintage' tones rely on vintage designs, including the easily saturated output transformers.

I've worked with a number of high-end distortion processors over the years and – although they're getting closer – they have yet to achieve the same complex sound quality provided by a tube amp running fully saturated. The practical question, and one that I've grappled with more than once, is how much is the gap in sound quality worth?

*Bryan Bergeron*

## CHIRPER CHATTER

How can the basic test circuit (Figure 17) for the November 2012 Chirper project be made adjustable within a small range for both time on and cycle rate? My objective is to make my own flasher controller that can be adjusted from slow (0.5 Hz) to fast (2 Hz), and the duty cycle for the turn signal light to be on from 25% to 75% of the flash rate. Some of this range may not be suitable, but I want to see what this could be like. Thanks.

**Tedd Lovell  
The Dalles, OR**

**Response:** As it turns out, changing the frequency and/or duty cycle of a 555 based astable oscillator is as easy as changing two resistors. For the moderate changes you're talking about, you wouldn't need to change the capacitor (C2).

If you want continuous variability and you have some means (an oscilloscope) to be able to measure the waveform, I'd add a couple of potentiometers. I'd put a 200K pot in series with R3, and replace R4 with a 4.7K ohm resistor in series with another 200K pot. You would have continuously variable 'on' time from about 65 ms to about 2.8 seconds, and continuously variable 'off' time from about 32 ms up to about 1.4 seconds. The pot adjustments are interactive, so you'll need to play with them to get the exact timing you want to see.

The 555 won't allow duty cycles below 50%. For that, use an inverter on the output (I'd use an NPN transistor and a couple of resistors); that'll reverse the output so that, for example, a 60% duty cycle becomes 40%.

A trick for observing the waveform using a non-storage oscilloscope is to scale the time with the capacitor. For example, using a .01  $\mu$ F capacitor in place of the 10  $\mu$ F will speed it up by a factor of 100. Instead of a one second cycle, you can view it at 10 ms.

You can tweak the adjustments at this faster speed, then replace the capacitor and scale it back to one second. Be aware, though, that unless you use precision capacitors, the scaling factor won't be exactly 100 as it will be affected by the capacitor's tolerances.

Check out TI's LM555 datasheet. It's available online at [www.ti.com/lit/ds/symlink/lm555.pc](http://www.ti.com/lit/ds/symlink/lm555.pc).

Good luck and have fun!

*Mike Huddleston KJ4LN*

## CONTEMPLATING IN VANE(S)

I would like to add something to Bryan Bergeron's discourse on Crookes' radiometer in his January 2013 editorial. I don't think there is even a partial vacuum inside.

Radiation falling on the black side of the vanes is absorbed, the black side warms up, and consequently warms the adjacent air which expands and in so doing, pushes on the black side of the vanes. This does not happen on the shiny side of the vanes as the radiation is reflected. With no expanding air pushing on the shiny side, the radiometer vanes will rotate towards the shiny side.

Now to the interesting part. Imagine that you could pull a really good vacuum inside the radiometer. Also imagine that you could get rid of bearing friction (think magnetic levitation).

Radiation has momentum. The relation between the



energy carried in and the momentum is  $E = pc$  where  $c$  is the velocity of light. It is also true that a change in momentum gives rise to a force. It's as simple as  $F(\text{force}) = \Delta p / \Delta t$ . (I'm 80 years old and don't have the "tech" to put these equations in the right way.) Anyway, consider what happens on the black side.

The light comes in and is absorbed. The change in momentum is just whatever momentum the radiation had and this results in a force. Now consider what happens on the shiny side. Remember that momentum is a vector quantity. You have twice the change in momentum on the shiny side as on the black side and twice the force.

Remember the change from going in to going out is twice that of going in and stopping. The radiometer vanes should rotate towards the black side. I don't know that this has ever been observed. The forces are very small.

Well, thanks for letting this old man have his say.

Dean Kaul

**Response:** Thanks for the note, Dean.

One reason I have the radiometer on my desk is because there are several theories as to why it works or shouldn't work the way it does.

We could look at the wave nature of light or the particle nature – as you have – or delve into quantum physics. I like your argument, as well. Yet another reason to keep the bulb where it is!

Bryan Bergeron

I decided to delve into how a Crookes' radiometer (light-mill) works a bit more.

I think I came across a definitive paper on the subject. Just go to Google and type in "How does a light-mill work?" It mentions that you need a partial vacuum.

It also mentions that the explanation I gave that the warmer air near the dark side of the vane is warmed, expands, and pushes the vane forward is wrong. However, I don't feel too bad because the article says that the Encyclopaedia Britannica still gives this erroneous explanation.

Out of curiosity, I did a calculation of the radiation forces in a perfect vacuum.

I took the intensity of the input light to be 10 solar constants. (I'm sure an arc lamp could do it a lot better.) Anyway, with an input intensity of 13.6 kilowatts per square meter, the force on an absorbing 1 cm square would be 16.3 billionths of an ounce.

I believe it when they say, "The experiment is very difficult."

Dean Kaul

**Response:** Yes, it is a partial vacuum.

I actually built a few of these things in high school physics.

We had a mercury vacuum pump – things didn't start happening until most of the atmosphere was evacuated. The most difficult part of construction is balancing the vanes so the contraption sits level on the needle bearing.

Glad you find the 'simple' device fascinating.

Bryan

## Wi-Fi Module & Dev Kit

### Industry's First

#### Embedded HTML5 WebSocket Server

Control hardware with a web browser on  
iPhone, iPad, Android, PC or Mac

#### Module

- WebSocket server enables real-time bidirectional socket communication between module and browser
- Embedded web server
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- 2 DACs, 8 ADCs and 14 Digital IOs
- Program 100% in JavaScript
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\$129



#### Development Kit

- LEDs, buttons and pots for digital and analog IOs
- Temperature and light sensors
- Battery, antenna & speaker
- Javascript source code to demo all hardware features

Compatible with current browsers:



## Bluetooth Keyboard Adapter

- Turns any USB/PS2 keyboard into a Bluetooth keyboard
- Works with any phone, tablet or PC that supports HID Bluetooth keyboard
- High-capacity Rechargeable battery



\$59

## Battery Capacity Tester



\$99

- PC software controls and records discharge of battery, plots curve and calculates total mAh and energy
- USB based. Green PC software (no installation necessary. Just download and run)

## Telephone Caller ID Manager

- PC software records caller ID with notes typed in by user
- When a call comes in, pops up window with call history and notes previously recorded
- USB based. Green PC software



\$99



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## >>> QUESTIONS

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[www.nutsvolts.com/tech-forum](http://www.nutsvolts.com/tech-forum)  
to view and answer  
new questions as they come in.

### Dog Zapper Circuit Needed

Back in the 1970s, the now deceased publication of *Popular Electronics* printed a construction article using readily available components to build a device that used battery power to generate a high voltage spike to electrify a piece of wire. An electric fence, if you will. I built it (at the time) so my boss could train his dog not to urinate on his flowers. I was told it worked great. I built it again, years later, to test the capabilities of another circuit to suppress voltage surges. The schematic for the circuit is long gone and so is the publication. We called it the "Dog Zapper" when we initially built the circuit. I'm not sure that was the name used in the construction article. If someone out there can give me some information on the circuit (or a similar one), or the month and year of the publication that contained the construction article, it would be greatly appreciated.

#2131

**L Tallman**  
Orange, CA

### Inductive Kick Diode

I built a PWM controller for a 36 volt golf cart motor. What size, amperage and voltage do I need for the motor's fly-back diode?

#2132

**Edwin Fitzpatrick**  
Ellijay, GA

### Low Audio On Dish Receiver

I'm looking for a schematic for a Dish Network satellite receiver model DISH311. The audio is too low and I'm wondering if there was any adjustment that could be made to increase it.

#2133

**Wayne Carpenter**  
Omak, WA

## >>> ANSWERS

**[#7121 - July 2012]**

### Modify Scott 340A Tube Receiver

*I live very close to a huge water tank that affects stereo reception. I would like to connect a scope to measure FM multipath distortion. I have had no luck getting help from user groups, etc., so far! Does anyone know exactly how to do this? I can't afford the McIntosh tuners. I can do the construction if I had a schematic. Is this possible?*

The first place I saw the oscilloscope multipath display was on the Marantz 10b. Two other FM tuners with the scope outputs were the Scott 312 (and the Scott 312b, plus the kit versions LT112 and LT-112b) and the Heathkit AJ-15 (and the receiver version AR-15). You need an X-Y oscilloscope — preferably with response down to DC. Connect the horizontal X input to the output from the audio detector (still monophonic, not yet demultiplexed) and connect the vertical Y input to the AGC (automatic gain control) signal.

**Joseph Feng**  
via email

**[#1131 - January 2013]**

### Microcontroller Newbie

*I'm just starting in electronics and have taught myself some of the basics through reading books and building kits. I'm intrigued with microcontroller projects and was hoping to get some seasoned opinions on where to start.*

*There seem to be several popular platforms that get most of the attention such as Arduino, PIC, Stamp, Propeller, etc.*

*Which is best for a beginner?*

*Can someone recommend a book on programming that assumes zero experience and explains the basics from the start through getting a simple project up and running?*

*Are there any beginner-friendly online user groups I might join?*

*Any advice is appreciated.*

I recommend the BASIC Stamp modules from Parallax because newcomers find them easy to use. In addition, Parallax has many books and manuals, as well as kits that get beginners off to a good start. I also like the Arduino Uno because of widespread support from users. The compatible Digilent chipKIT Uno32 provides a more powerful processor and will appeal to people who want to move beyond the eight-bit Atmel chip used in the original Arduino Uno. The kits mentioned use a 5V power source and work with 5V logic devices. Other boards — such as the ARM mbed and BeagleBone — operate from 5V, too, but the I/O pins provide 3.3V logic levels. You might find it difficult to breadboard with 3.3V logic chips, most of which come in surface-mount packages.

**Jon Titus**  
Herriman, UT

**[#12121 - December 2012]**

*Does anyone have a schematic for*

Send all questions and answers by email to [forum@nutsvolts.com](mailto:forum@nutsvolts.com)  
or via the online form at [www.nutsvolts.com/tech-forum](http://www.nutsvolts.com/tech-forum)

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*Always use common sense and good judgment!*



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or via the online form at [www.nutsvolts.com/tech-forum](http://www.nutsvolts.com/tech-forum)

a simple light meter? I'm trying to determine the difference in illumination provided by CFLs as opposed to incandescent light bulbs. I'm not too interested in the absolute value of the light hitting the surface, just the relative difference between the two.

I did an experiment a few months ago using a serial port as a light meter that can log brightness data to a file. I posted it at [www.cedarlakeinstruments.com/blog/?p=10](http://www.cedarlakeinstruments.com/blog/?p=10). The software I wrote to display data isn't online, but I can email it to you if you'd like. Just contact me at [www.cedarlakeinstruments.com](http://www.cedarlakeinstruments.com). Here is the posting:

The lowest cost way I could think of was to avoid a microcontroller or other logic component and use whatever was already on a modern PC. My idea was to use a Cadmium Sulphide (CdS) photocell. CdS cells are used in many camera light meters

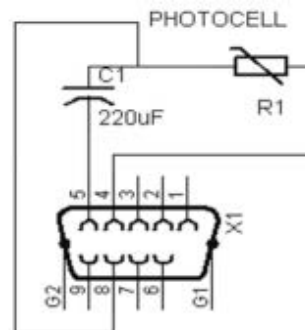
and work by changing resistance in response to ambient light. By using the current through a photocell to charge a capacitor, we can tell the light level by measuring the time taken to charge. In days of old, we could have used a joystick port to do this, but those are long gone, now replaced by USB-connected joysticks.

On PCs without joystick ports, we could have done the same thing with the printer port. However, those are also a thing of the past.

So far, most PCs still come with serial ports, so we'll try those. The Clear To Send (CTS) and Data Terminal Ready (DTR) lines can be controlled from a Win32 or .NET application. There is some concern about the responsiveness of Windows, but as long as we avoid very short time constants, we can get usable data.

The concept is to build an RC circuit from a photocell and a  $200\ \mu\text{F}$

capacitor. The photocell is driven from the DTR line, and the junction of the capacitor and photocell is read by the CTS input. Here's the schematic; it's pretty simple:



The results are surprisingly useful. Discharging the circuit for two seconds and then charging it while polling the CTS line every five milliseconds shows a clear difference as the photocell is pointed at various areas of a lighted room.

**Lyndon  
via email**



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# Valentine's Day Goodies!

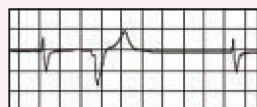
## Electrocardiogram ECG Heart Monitor

- ✓ Visible and audible display of your heart rhythm!
- ✓ Bright LED "Beat" indicator for easy viewing!
- ✓ Re-usable hospital grade sensors included!
- ✓ Monitor output for professional scope display
- ✓ Simple and safe 9V battery operation



February is the month for Valentine's Day, and what a great time to think of your heart! Not how many times it's been broken, not how many times it's fallen head over heels in love, but how it actually works... and how it's doing these days! Not only will building an actual ECG be a thrill, but you'll get hands-on knowledge of the relationship between electrical activity and the human body. Each time the human heart beats, the heart muscle causes small electrical changes across your skin. By monitoring and amplifying these changes, the ECG1C detects the heartbeat and allows you to accurately display it, and hear it, giving you a window into the inner workings of the human heart and body!

Use the ECG1C to astound your physician with your knowledge of ECG/EKG systems. Enjoy learning about the inner workings of the heart while, at the same time, covering the stage-by-stage electronic circuit theory used in the kit to monitor it. The three probe wire pick-ups allow for easy application and experimentation without the cumbersome harness normally associated with ECG monitors.



Look what I found!

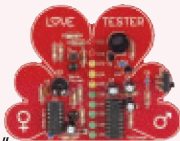
when I noticed some skipped beats in my pulse! An immediate cardiac check found I had Trigeminy, or PVCs that occur at intervals of 2 normal beats to one PVC! And I saw it with our ECG1C kit!

The fully adjustable gain control on the front panel allows the user to custom tune the differential signal picked up by the probes giving you a perfect reading and display every time! 10 hospital grade re-usable probe patches are included together with the matching custom case set shown. Additional patches are available in 10-packs. Operates on a standard 9VDC battery (not included) for safe and simple operation. Note, while the ECG1C professionally monitors and displays your heart rhythms and functions, it is intended for hobbyist usage only. If you experience any cardiac symptoms, seek proper medical help immediately!

ECG1C	Electrocardiogram Heart Monitor Kit With Case & Patches	\$44.95
ECG1WT	Electrocardiogram Heart Monitor, Factory Assembled & Tested	\$89.95
ECGP10	Electrocardiogram Re-Usable Probe Patches, 10-Pack	\$4.95

## Electronic Love Tester

- ✓ 10 LED love scale display!
- ✓ Audible love level sound!
- ✓ Great party fun!
- ✓ Heart shaped PC board!

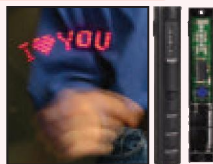


This uniquely shaped "Love Tester" is the ultimate gag for any couple! Designed to check your love life, each partner holds one end of the tester PCB at the appropriate male and female touch pads. Then they romantically join hands and watch the results on the love meter! 10 green, yellow, and red LEDs act like a scale, and just like the carnival, when it hits the top they flash, indicating you're a red hot couple! There is also an audible alarm that changes with the "love level". Next time the party isn't going anywhere, bring this out, it's a riot! Compatible with all couples! Runs on a standard 9V battery (not included)

MK149	Electronic Love Tester Kit	\$16.95
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## LED Magic Wand

- ✓ Message floats in air!
- ✓ Fun at concerts & events!
- ✓ High visibility red LEDs
- ✓ Pre-programmed or custom messages

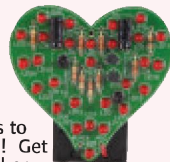


Use the "Magic Wand" to display your true feelings! Simply shake it back and forth and brilliant messages seem to appear in mid-air! Six high intensity LEDs are microprocessor controlled to display messages and graphics that are pre-programmed into the wand. You can also custom program a message of your choice! From amazing your friends, making a statement at a concert, or simply telling your loved one how you feel, the message wand can't be beat! Runs on two AAA batteries (not included), and features auto power-off.

MK155	LED Magic Wand Kit	\$17.95
-------	--------------------	---------

## LED Flashing Heart

- ✓ 28 brilliant red LEDs!
- ✓ Unique dual heart design!
- ✓ Freestanding mount!



What a way to display your feelings to that very special person in your life! Get out your soldering iron and dazzle her with this unique dual heart electronic display that you can say you built yourself!

28 brilliant red LEDs are formed into two separate heart designs on the heart shaped PC board creating a great flashing display that's easy to assemble. Built-in battery holder base makes the sweetheart freestanding and perfect for a desk or table. Runs on a standard 9V battery (not included). Measures 2.4" x 2.4" x 1.2".

MK101	LED Flashing Sweetheart Kit	\$6.95
-------	-----------------------------	--------

## SMT LED Heart Display

- ✓ Alternating flashing!
- ✓ 6 super bright SMT LEDs!
- ✓ Learn all about SMT!
- ✓ Definitely gets her attention!



This cute little kit gives you a distinctive red display using 6 Surface Mount (SMT) LEDs. The PC board is in the shape of a red heart. The small size makes it perfect to be used as a badge or hanging pendant around your neck. Even better as an illuminated attention-getting heart to accompany a Valentine's Day card! Makes a great SMT learning kit to bring you into the world of SMT technology, design, and hands-on soldering and troubleshooting. Don't worry, extra SMT parts are included just in case you lose or damage any! Runs on a small CR2025/32 button cell (not included). Measures 1.9" x 1.7" x .3".

MK144	SMT Flashing Heart Kit	\$11.95
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## Ultimate 555 Timers

This new series builds on the classic UT5 kit, but takes it to a whole new level! You can configure it on the fly with easy-to-use jumper settings, drive relays, and directly interface all timer functions with onboard controls or external signals.



All connections are easily made through terminal blocks. Plus, we've replaced the ceramic capacitor of other timer kits with a Mylar capacitor which keeps your timings stable over a much wider range of voltages! Available in through hole or surface mount versions! Visit [www.ramseykits.com](http://www.ramseykits.com) for version details.

UT5A	Through Hole 555 Timer/Osc Kit	\$21.95
UT5AS	SMT 555 Timer/Osc Kit	\$29.95

## USB PIC Programmer

Finally, a compact USB PIC Programmer with a 20 pin ZIF socket for easy programming of most Microchip PIC Flash devices that does not require low voltage programming. Plus it uses USB, therefore no more RS232 compatibility blues!



CK1301	USB PIC Programmer Kit	\$34.95
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## Doppler Direction Finder

Track down jammers and hidden transmitters with ease! 22.5 degree bearing indicator with adjustable damping, phase inversion, scan and more. Includes 5 piece antenna kit. Runs on 12VDC vehicle or battery power.



DDF1	Doppler Direction Finder Kit	\$169.95
------	------------------------------	----------

## Digital Recorder/Player

This little board records and plays back up to 8 minutes of audio! Features a on-board electret mic as well as line input and output and speaker output! Adjustable sample rate to match your application. Runs on 9-12VDC.



K8094	Audio Storage Module Kit	\$32.95
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## HV Plasma Generator

Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20kHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.



PG13	HV Plasma Generator Kit	\$64.95
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## Speedy Speed Radar Gun

Our famous Speedy radar gun teaches you doppler effect the fun way! Digital readout displays in MPH, KPH, or FPS. You supply two coffee cans! Runs on 12VDC or our AC121 supply.



SG7	Speed Radar Gun Kit	\$74.95
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## Broadband RF Preamp

Need to "perk-up" your counter or other equipment to read weak signals? This preamp has low noise and yet provides 25dB gain from 1MHz to well over 1GHz. Output can reach 100mW! Runs on 12 volts AC or DC or the included 110VAC PS. Assmb.



PR2	Broadband RF Preamp	\$69.95
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## Van de Graaff Generators

Create your own lightning with these time tested student favorites! Produces low current static currents that can be "shocking" but perfectly safe! Draw sparks to a screwdriver, grab hold and watch your hair stand straight up! Two models produce from 200kV to 400kV!



VG	Van de Graaff Generators	from \$139.95
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## Four-Mode Vehicular Keyless Entry Test Set



Ahh!... the conveniences of today's technology in our modern world! Voice recognition, LED's instead of incandescent bulbs, on-board computers, on-board hard drives, automatic parallel parking, automatic radar cruise control, and of course, wireless remote controls! They make it so simple, just have the "key" (called a key fob) somewhere in your pocket or purse, get near the vehicle, it knows that you are there! Touch the door handle and the vehicle unlocks. Get in and touch the start button and the vehicle starts. You have yet to use a key through the whole process! And don't forget all the wireless controls for your house lights, building access and entertainment systems. They're so great... until they don't work!

Testing your system is easy. To test the complete key fob-to-vehicle and vehicle-to-key fob communications path just stand close to the vehicle with the WCT3 and your key fob in hand. Press the test button and the WCT3 will detect and display the presence of the vehicle's 125kHz/20KHz signal and, if they "handshake", will also detect and display the presence of your key fob's 315MHz return signal. You can independently test key fob only signals (panic, lock, trunk, etc.) by holding the key fob near the WCT3, pressing the test button, and pushing the function button on the key fob. The same functionality testing can be done with IR key fobs. The modulated IR signal is detected and will illuminate the IR test LED on the test set. If you know a few "secrets" you can also see if the tire pressure sensors/transmitters are generating signals or the built-in garage door opener in your rear view mirror is transmitting a signal! But the WCT3's uses go beyond the automotive world. The majority of building wireless access systems also utilize 125 kHz. Just hold the test set near the building access sensor and the WCT3 will detect the 125 kHz signal. That will help you troubleshoot door access locations that are not working. It gets even better... you can use the WCT3 to test virtually any other 315 MHz, 433 MHz, 125kHz, 20kHz and IR wireless control system to verify generation of a signal. The WCT3 test set is housed in a compact 2.25" x 4.6" x 9" case and is powered by a standard 9VDC battery (not included).

**WCT3 Four Mode Keyless Entry Test Set Kit**

**\$59.95**

## Passive Aircraft Monitor

**PATENTED!**

The hit of the decade! Our patented receiver hears the entire aircraft band without any tuning! Passive design has no LO, therefore can be used on board aircraft! Perfect for air-shows, hears the active traffic as it happens! Available kit or factory assembled.



**ABM1 Passive Aircraft Receiver Kit \$89.95**

## Voice Activated Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch or to turn on a recorder or light! Directly switches relays or low voltage loads up to 100mA. Runs on 6-12 VDC.



**VS1 Voice Switch Kit \$9.95**

## OBDII CarChip Pro

The incredible OBDII plug-in monitor that has everyone talking! Once plugged into your vehicle it monitors up to 300 hours of trip data, from speed, braking, acceleration, RPM and a whole lot more. Reads and resets your check engine light, and more!



**8226 CarChip Pro OBDII Monitor-Asmb \$79.00**

## 5A PWM Motor Speed Controller

This handy controller uses a pulse width modulated output to control the speed of a motor without sacrificing torque! Handles a continuous current of 5A and includes LED to indicate speed as well as an oversized gold heatsink! Also available factory assembled.



**CK1102 5A PWM Motor Controller Kit \$14.95**

## Digital LED Thermometer

This handy thermometer reads Celsius or Fahrenheit on an eye-catching .56" LED display! Based on the DS18B20 sensor and controlled by a PIC, it has a range of -67°F to 257°F (-55°C to 125°C) with a wired remote range of 325 feet!



**CK127 Digital LED Thermometer Kit \$29.95**

## Tone Encoder/Decoder

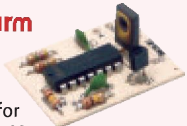
Encode and decode with the same kit! This little mini-kit will simultaneously encode and/or decode any audio frequency between 40Hz and 5,000 Hz! Precision 20-turn trim pot adjustment! 5-12VDC.



**TD1 Tone Encoder/Decoder Kit \$9.95**

## Mad Blaster Warble Alarm

If you need to simply get attention, the "Mad Blaster" is the answer, producing a LOUD ear shattering raucous racket! Super for car and home alarms as well. Drives any speaker. Runs on 9-12VDC.



**MB1 Mad Blaster Warble Alarm Kit \$9.95**

## Laser Light Show

Just like the big concerts, you can impress your friends with your own laser light show! Audio input modulates the laser display to your favorite music! Adjustable pattern & speed. Runs on 6-12VDC.



**L51 Laser Light Show Kit \$49.95**

## Optically Isolated Module

The hobbyist's headache solver! Converts any AC or DC signal to logic level. The beauty is that the input and output are totally isolated from each other! Output can drive up to 150mA at 40VDC.



**OM2 Optically Isolated Module Kit \$16.95**

## Water Sensor Alarm

This little \$7 kit can really "bail you out"! Simply mount the alarm where you want to detect water level problems (sump pump)! When the water touches the contacts the alarm goes off! Sensor can even be remotely located. Runs on a standard 9V battery.



**MK108 Water Sensor Alarm Kit \$6.95**

## 12VDC Regulated Switching Supply

Go green with our new 12VDC 1A regulated supply. Worldwide input 100-240VAC with a Level-V efficiency! It gets even better, includes DUAL ferrite cores for RF and EMI suppression. All this at a 10 buck old wallwart price! What a deal!



**AC121 12VDC 1A Regulated Supply \$9.95**

## Air Blasting Ion Generator

Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.



**IG7 Ion Generator Kit \$64.95**

## Tickle-Stick Shocker

The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC.



**TS4 Tickle Stick Kit \$9.95**

## Tri-Field Meter Kit

**THE GHOST DETECTOR!**

"See" electrical, magnetic, and RF fields as a graphical LED display on the front panel! Use it to detect these fields in your house, find RF sources, you name it. Featured on CBS's Ghost Whisperer to detect the presence of ghosts! Req's 4 AAA batteries.



**TFM3C Tri-Field Meter Kit \$74.95**

## Electronic Watch Dog

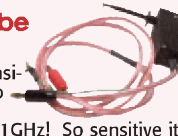
A barking dog on a PC board! And you don't have to feed it! Generates 2 different selectable barking dog sounds. Plus a built-in mic senses noise and can be set to bark when it hears it! Adjustable sensitivity! Unlike my Saint, eats 2-8VAC or 9-12VDC, it's not fussy!



**K2655 Electronic Watch Dog Kit \$39.95**

## Sniff-It RF Detector Probe

Measure RF with your standard DMM or VOM! This extremely sensitive RF detector probe connects to any voltmeter and allows you to measure RF from 100kHz to over 1GHz! So sensitive it can be used as a RF field strength meter!



**RF1 Sniff-It RF Detector Probe Kit \$27.95**

## Classic Nixie Tube Clocks **HOT SELLER!**



Our next generation of classic Nixie tube clocks perfectly mesh today's technology with the Nixie era technology of the 60's. Of course, features you'd expect with a typical clock are all supported with the Nixie clock... and a whole lot more!

The clocks are programmable for 12 or 24 hour mode, various AM/PM indications, programmable leading zero blanking, and include a programmable alarm with snooze as well as date display, 4 or 6 tube, kit or assembled!

We then jumped the technological time line of the 60's Nixie displays by adding the latest multi-colored LEDs to the base of the Nixie tubes to provide hundreds of illumination colors to highlight the glass tubes! The LED lighting can be programmed to any color and brightness combination of the colors red, green, or blue to suit your mood or environment.

Then we leaped over the technological time line by integrating an optional GPS time base reference for the ultimate in clock accuracy! The small optional GPS receiver module is factory assembled and tested, and plugs directly into the back of the clock to give your Nixie clock accuracy you could only dream of!

The clocks are available in our signature hand rubbed Teak & Maple, polished aluminum, or clear acrylic bases. You also have your choice of IN-14 or highly sought after IN-8-2 nixie tubes (for the 6-tube clock).

**NIXIE Classic Nixie Tube Clock Kits From \$229.95**

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PORTABILITY & PERFORMANCE



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Bandwidth	60 MHz	100 MHz	200 MHz
<b>Buffer memory</b>	<b>8 MS</b>	<b>32 MS</b>	<b>128 MS</b>
Resolution (enhanced)	8 bits (12 bits)		
Signal generator	Function generator + AWG		
Price	\$1070	\$1400	\$1730